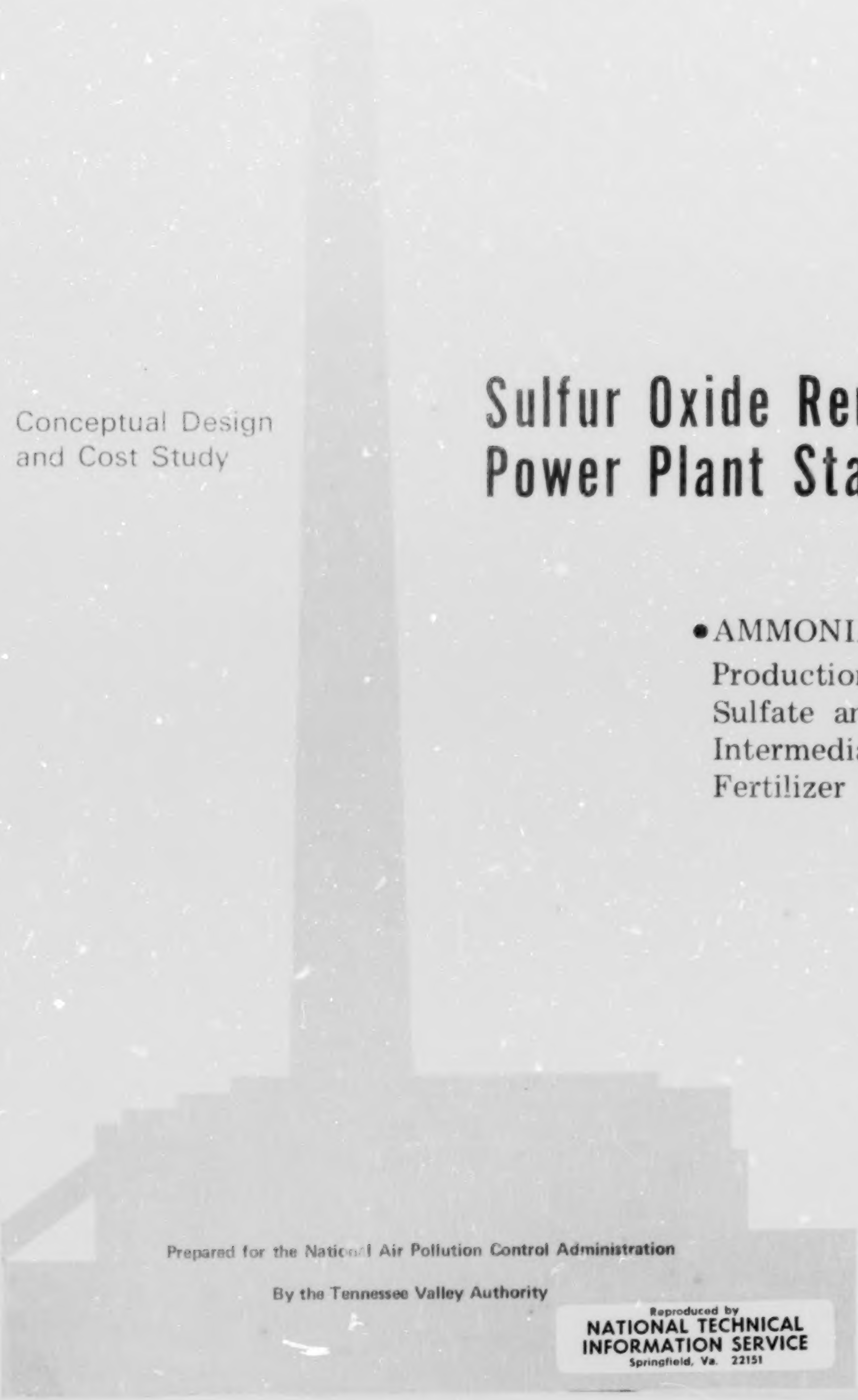
APTD-0675

PB 196 804



Conceptual Design
and Cost Study

Sulfur Oxide Removal From Power Plant Stack Gas

• AMMONIA SCRUBBING
Production of Ammonium
Sulfate and Use as an
Intermediate in Phosphate
Fertilizer Manufacture

Prepared for the National Air Pollution Control Administration

By the Tennessee Valley Authority

1970

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
Springfield, Va. 22151

324

STANDARD TITLE PAGE FOR TECHNICAL REPORTS

1. Report No. APTD-0615

2. Govt. Accession No.

3. Recipient's Catalog No.

4. Title and Subtitle
Sulfur Oxide Removal From Power Plant Stack Gas
Ammonia Scrubbing - Conceptual Design and Cost Study Series

5. Report Date
September 1970

6. Performing Organization Code

7. Author(s)

8. Performing Organization Rept. No. TV-29233A

9. Performing Organization Name and Address
Tennessee Valley Authority
Muscle Shoals, Ala. 35660

10. Project/Task/Work Unit No.

11. Contract/Grant No.
No contract number

12. Sponsoring Agency Name and Address
National Air Pollution Control Administration Technical Center
411 West Chapel Hill Street
Durham, North Carolina 27701

13. Type of Report & Period Covered

14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstracts

Ammonia scrubbing and production of phosphate fertilizer has promise, under certain conditions, as a method for recovering sulfur oxides from stack gases. The main economic factors are product volume (depending on power plant size and S content of coal), net sales revenue, and basis of financing. Private industry participation in financing and operation appears unlikely because of the high projected cash flow necessary to attract capital. There is a net profit for plants about 500 mw and larger but it is not large enough to attract investment except perhaps under special conditions. The situation is improved if there is supplemental income in the form of a payment for the service of sulfur oxide control; in this case the larger product volumes (e.g., 1000 mw at 3.5% S in coal or 500 mw at 5% S) give a projected total income adequate for financing. The economics under power industry financing are more promising. For plants 500-600 mw and larger in size the recovery method is favored over limestone - wet scrubbing because there is less deficit passed on to the power consumer after payment to investors of the regulated return on investment. Only a few recovery installations of this type can be accommodated by the fertilizer market.

17. Key Words and Document Analysis. 17a. Descriptors

Air pollution control equipment
Sulfur oxides
Steam electric power generation
Flue gases
Ammonia
Scrubbers
Design criteria
Expenses
Fertilizers
Heat transfer

17b. Identifiers/Open-Ended Terms

17c. COSATI Field/Group 13/02, 07/01

18. Distribution Statement
Unlimited

19. Security Class (This Report)
UNCLASSIFIED

20. Security Class (This Page)
UNCLASSIFIED

21. No. of Pages
322

22. Price

FORM CFSTI-35 (4-70)

USCOMM-DC 65002-P70

Sulfur Oxide Removal From Power Plant Stack Gas

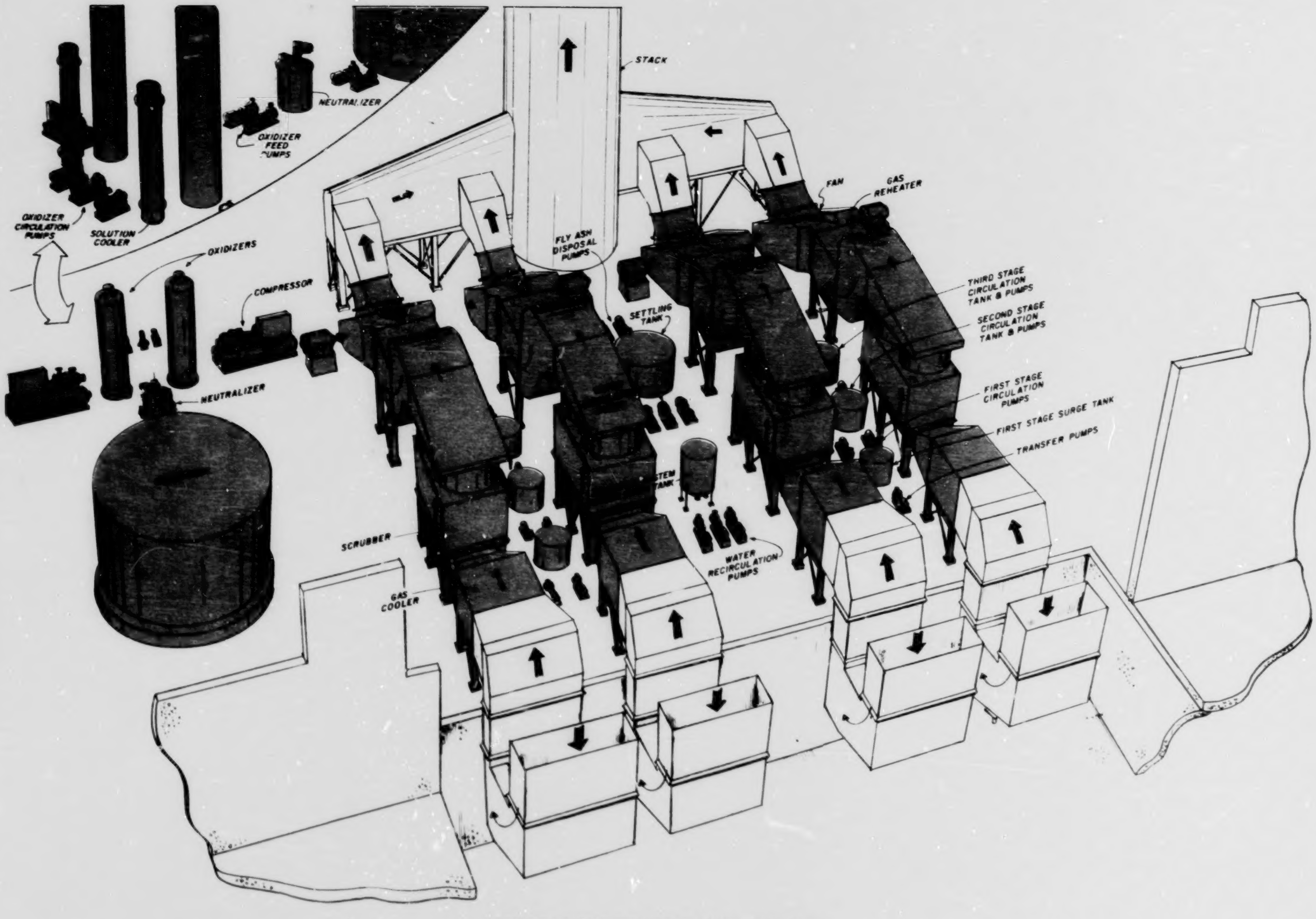
•AMMONIA SCRUBBING
Production of Ammonium Sulfate and Use as an Intermediate in Phosphate Fertilizer Manufacture

Conceptual Design and Cost Study Series
Study No. 3

Prepared for
National Air Pollution Control Administration
(U. S. Department of Health, Education, and Welfare)

By
Tennessee Valley Authority

Contract No. TV-29233A


STACK
NEUTRALIZER
OXIDIZER FEED PUMPS
OXIDIZER CIRCULATION PUMPS
SOLUTION COOLER
OXIDIZERS
COMPRESSOR
NEUTRALIZER
FLY ASH DISPOSAL PUMPS
SETTLING TANK
FAN
GAS REHEATER
THIRD STAGE CIRCULATION TANK & PUMPS
SECOND STAGE CIRCULATION TANK & PUMPS
FIRST STAGE CIRCULATION PUMPS
FIRST STAGE SURGE TANK
TRANSFER PUMPS
STEM TANK
WATER RECIRCULATION PUMPS
SCRUBBER
GAS COOLER

POWER PLANT EQUIPPED WITH AMMONIA
SCRUBBING PROCESS FOR SULFUR OXIDE REMOVAL
SCRUBBING EQUIPMENT SHOWN IN COLOR

PREFACE

On February 16, 1967, the National Center for Air Pollution Control (Public Health Service, U. S. Department of Health, Education, and Welfare) entered into a contract with the Tennessee Valley Authority (TVA) for a series of conceptual design and economic studies to be carried out by TVA on processes for reduction of sulfur oxide emissions from power generation. The purpose is to evaluate objectively and realistically the merits of different methods under consideration for sulfur oxide control, with a common and uniform basis used for comparison.

Various types of activities enter into the studies, including (1) analysis of the published literature bearing on the process, (2) direct contacts to obtain information from organizations currently working on the process or in fields allied to it, (3) bench- and plant-scale tests to fill in gaps in the information, (4) specific studies by specialists in power plant design, power plant operation, and air and water pollution to supplement the main conceptual design study, (5) market studies for processes involving recovery of a salable product, (6) quotations from vendors and fabricators on major pieces of equipment, and (7) detailed cost estimates to cover a wide range of the parameters involved.

Work has proceeded on three processes: (1) limestone injection (dry process), (2) use of limestone in a wet-scrubbing process, and (3) ammonia scrubbing. Reports on the dry limestone injection and limestone - wet scrubbing studies were issued in mid-1968 and in mid-1969, respectively. Ammonia scrubbing, which has many variations and complications, has been broken down under several headings; the present report is concerned with the variations in which ammonium sulfate is obtained as an intermediate product and is then used in production of a fertilizer material.

The work has been divided in TVA as follows:

Project Supervision

Applied Research Branch (Division of Chemical Development)

Cost Estimates

Applied Research Branch
Design Branch (Division of Chemical Development)
Financial Planning Staff (Office of Power)

Report Preparation

Applied Research Branch
Air Quality Branch (Division of Environmental Research and Development)
Distribution Economics Section (Division of Agricultural Development)

A major part of the evaluation has been the analysis of findings by other organizations who have worked on ammonia scrubbing. These findings, which are, of course, the basis for the conceptual design, are used throughout the body of the report and are referenced in an annotated bibliography. In addition to published literature, several organizations have supplied information directly for use in the study; the contributions of the following are acknowledged.

American Air Filter Company, Inc.
Bloom Engineering Company, Inc.
Brownlee-Morrow Engineering Company, Inc.
C and I/Girdler Inc.
The Ceilcote Company
Chemical Construction Corporation
Chicago Blower Corporation
Cominco Ltd. (Canada)
Continental Manufacturing Company
Dorr-Oliver Incorporated
Dresser Industries, Inc.
Dutch State Mines (The Netherlands)
Electricite de France (France)
Federal Power Commission
Fuel Research Institute (Czechoslovakia)
Japan Engineering Consulting Company (Japan)
Kuhlmann (France)
Mitsubishi Shoji Kaisha, Ltd. (Japan)
National Air Pollution Control Administration (NAPCA)
National Dust Collector Corporation
Perfex Corporation
Riley Stoker Corporation
Simon Engineering Ltd. (England)
The W. W. Sly Manufacturing Company
Therm-Mech, Inc. [Brown Fintube Company (Representative)]
Universal Oil Products Company (Air Correction Division)
Otto H. York Company, Inc.

Reports in this series can be obtained from

Clearinghouse for Scientific
and Technical Information
5285 Port Royal Road
Springfield, Virginia 22151

The reports are identified and priced as follows:

Title	Number	Price
Sulfur Oxide Removal from Power Plant Stack Gas—Sorption by Limestone or Lime (Dry Process)	PB 178-972	$3.00
Sulfur Oxide Removal from Power Plant Stack Gas—Use of Limestone in Wet-Scrubbing Process	PB 183-908	3.00
Sulfur Oxide Removal from Power Plant Stack Gas—Ammonia Scrubbing: Production of Ammonium Sulfate and Use as Intermediate in Phosphate Fertilizer Manufacture	*	*

*Not yet assigned.

CONTENTS

SUMMARY 9
- Study assumptions 9
- Process equipment 10
- Economic considerations 10
- Capital required 11
- Profitability 11
- Conclusions and recommendations 12

INTRODUCTION 14

PROCESS VARIATIONS IN AMMONIA SCRUBBING 16
- Scrubber design and operation 16
- Treatment of scrubber effluent 16
- Use of ammonium sulfate 19

HISTORY AND STATUS 23

CHEMISTRY AND KINETICS OF SULFUR OXIDE ABSORPTION 25
- Equilibria involved 25
- Vapor pressure 25
- pH 27
- Solubility 29
- Viscosity and specific gravity 29
- Kinetics and mass transfer 31

FORMATION OF AMMONIUM SULFATE 37
- Oxidation in the scrubber 37
- Oxidation in separate vessel 40
- Acidification 40

USE OF AMMONIUM SULFATE IN PHOSPHATE FERTILIZER PROCESSES 43
- Nitric phosphate 43
- Ammonium phosphate-sulfate 46

MAJOR ECONOMIC CONSIDERATIONS 47
- Cost of alternative to recovery 47
- Return on investment 47
- Power plant capacity factor 49
- Sulfur content of coal 50
- Product marketing 52

STUDY ASSUMPTIONS AND DESIGN CRITERIA . . 54
- Plant size 54
- Sulfur content of fuel 54
- Degree of sulfur dioxide removal 54
- Dust removal 54
- Operating time and capacity factor 55
- Plant location 55
- Amount of storage 55
- Stack gas reheat 55
- Fertilizer technology 55
- Solids disposal 56
- Process indices 56
- General 56
- Operating indices for process A (28-14-0 production) 56
- Operating indices for process B (26-19-0 production) 56
- Operating indices for process C (19-14-0 production) 57

EQUIPMENT SELECTION AND DESCRIPTION 58
- Selected reported technology 58
- Major alternatives 65
- Equipment description 73

INVESTMENT AND OPERATING COST 81
- Investment 81
- Operating cost 81

PROFITABILITY AND ECONOMIC POTENTIAL . . . 93
- Market study 93
  - Fertilizer industry logistics 93
  - Pricing of recovery products 100
- Profitability 103
- Economic evaluation 108
  - Basic economics of fertilizer process 108
  - Fertilizer company involvement 109
  - Power company basis 111

RESEARCH AND DEVELOPMENT NEEDED 126
- Degree of oxidation in scrubber 126
- Control of bisulfite:sulfite ratio 126
- Dust removal 126
- Composition of scrubber liquor at steady state 126
- Corrosion 127
- Optimization of scrubber operation 127
- Use of ammonium sulfate 127

CONCLUSIONS AND RECOMMENDATIONS 128

REFERENCES AND ABSTRACTS 131

APPENDIX A: Optimum pricing strategy 140

APPENDIX B: Cost estimates 146

APPENDIX C: Drawings 314

TABLES

Page

S-1 Capital requirements for process A 11
S-2 Profitability of process A 11
S-3 Profitability of process A with supplementary income as payment for pollution abatement 12
S-4 Cost of recovery vs limestone - wet scrubbing under power company economics 12
1 Reactions of NH_3 with SO_2 and CO_2 25
2 Vapor pressures in the system NH_3-SO_2-H_2O ... 28
3 Values of constants A and B for viscosity calculations 32
4 Effect of SO_2:NH mole ratio on mass transfer gas velocity: 1.5-2 m/sec 34
5 Capital cost of limestone - wet scrubbing 47
6 Operating cost for limestone - wet scrubbing 48
7 Averaged operating conditions for pilot plant runs 59
8 Effect of pH on composition of the scrubber effluent 61
9 Variation of the coefficient of absorption with decrease in chemical capacity of the absorbing solution 69
10 Comparison of scrubber combinations 70
11 Scrubber comparison 72
12 Comparison of demisters 73
13 Tray composition conditions 75
14 Estimated tray efficiencies 77
15 Total fixed investment of ammonia scrubbing-fertilizer manufacturing facilities for existing power plants 81
16 Total fixed investment of ammonia scrubbing-fertilizer manufacturing facilities for new power plants 82
17 Annual capital charges for power industry financing - new power unit with 35-yr life 85
18 Lifetime operating costs for ammonia scrubbing processes in new 500- and 1,000-mw power units 86
19 Phosphate rock transporation cost via rail and barge from Tampa, Florida 93

Page

20 Nitrogen market profile in the Midwest, 1967 ... 96
21 Materials sold as custom mixtures in Illinois, 1966-1967 98
22 Fertilizer materials consumption and average consumption density for the Iowa-Illinois-Indiana area 98
23 Competitive bulk-blending prices for standard fertilizers and for sulfur oxide recovery products (delivered to the Midwest) 99
24 Average return to manufacturing process A (28-14-0) 102
25 Average return to manufacturing process B (26-19-0) 102
26 Average return to manufacturing process C (19-14-0) 102
27 Average return to manufacturing ammonium sulfate 103
28 Summary of estimated fixed investment requirements: manufacture of 28-14-0 fertilizer by sulfate recycle - nitric phosphate process 109
29 Nonregulated company economics - total venture annual manufacturing costs for 28-14-0 fertilizer using ammonium sulfate recycle and nitric phosphate process 110
30 Summary of estimated fixed investment requirements: manufacture of ammonium sulfate solution from waste gypsum ammonia, and carbon dioxide - sulfate recycle process for 28-14-0 nitric phosphate fertilizer 111
31 Annual manufacturing costs: ammonium sulfate solution (40%) from waste gypsum, ammonia, and carbon dioxide - sulfate recycle process for 28-14-0 nitric phosphate fertilizer 113
32 Economic potential of ammonia scrubbing - fertilizer production processes 114
33 Present worth of the net annual increase in cost of power resulting from use of the ammonia and limestone scrubbing processes 114

FIGURES

Page

1 Ammonia scrubbing: regeneration by stripping . . . 17

2 Ammonia scrubbing: acidification of effluent 18

3 Ammonia scrubbing: production of ammonium sulfate 19

4 Ammonia scrubbing: precipitation (zinc oxide) . . . 20

5 Ammonia scrubbing: use of $(NH_4)_2SO_4$ in production of phosphate fertilizer by nitric phosphate method 21

6 Ammonia scrubbing: use of $(NH_4)_2SO_4$ in production of phosphate fertilizer by bisulfate method 22

7 Ammonia scrubbing: acidification of effluent with NH_4HSO_4 22

8 Reactions of NH_3 with SO_2 and CO_2. 26

9 Effect of sulfate content on SO_2 vapor pressure 29

10 Equilibrium vapor pressure over ammonia sulfite-bisulfite solutions 30

11 Partial pressure of SO_2 in the system $(NH_4)_2S_2O_5$-$(NH_4)_2SO_3$-SO_2 31

12 pH of NH_4HSO_3-$(NH_4)_2SO_3$ solutions 32

13 Solubility diagram for the system NH_3-SO_2-SO_3-H_2O at 86° F 33

14 The system $(NH_4)_2SO_4$-$(NH_4)_2SO_3$-NH_4HSO_3-H_2O at 30° C 34

15 Solubility of $(NH_4)_2SO_4$ in the $(NH_4)_2SO_3$-NH_4HSO_3-H_2O system at 30° C 35

16 System $(NH_4)_2SO_3$-NH_4HSO_3-$(NH_4)_2SO_4$-H_2O . 36

17 Air oxidation of ammonium sulfite-bisulfite solution 41

18 Evaporation requirements for production of $(NH_4)_2SO_4$ from scrubber effluent 42

19 Ammonium phosphate nitrate by nitric phosphate route (sulfate recycle process) 44

20 Typical weekly load curve for TVA power system (spring 1968) 50

21 Annual variation of load in TVA power system . . . 51

22 Sulfur oxide emission and sulfur consumption in the U. S 53

23 Early TVA pilot plant for sulfur dioxide recovery by ammonia scrubbing 58

24 Effect of packing depth on SO_2 recovery at various liquor recirculation rates (at pH 6.4) 59

25 Effect of pH of scrubbing liquor on SO_2 recovery and NH_3 loss 60

26 SO_2 absorption in a venturi scrubber as a function of flow rate of absorbent for various gas velocities (w) in the scrubber throat 63

27 SO_2 absorption as a function of pressure drop in scrubber 64

Page

28 SO_2 absorption as a function of total consumption of electric power in a multistage venturi arrangement (the curve number corresponds to the number of stages; pump pressure: 40 mm H_2O) 65

29 Absorption of SO_2 by ammonium sulfite-bisulfite solution in wetted-wall absorber at varying concentrations of SO_2 in the inlet gas 66

30 Sieve-plate scrubber tested by Chertkov *et al* 67

31 Collection efficiency for 1-micron particles in impingement-type scrubber 69

32 Four-stage perforated plate-impingement scrubber with separate circulation of liquor streams 71

33 Four-stage scrubber with gas-liquid separation plates under SO_2 absorption stages 74

34 Relationship of N_{Og} and K , based on Chertkov data for sieve tray absorption of SO_2 in NH_3-SO_2-H_2O solution 76

35 Typical sly impinjet scrubber 78

36 Effect of power unit size on ammonia scrubbing - fertilizer plant investment (process A) 82

37 Effect of power unit size on ammonia scrubbing - fertilizer plant investment (process B) 83

38 Effect of power unit size on ammonia scrubbing - fertilizer plant investment (process C) 84

39 Effect of sulfur content of coal on total fixed investment 84

40 Effect of power unit size on annual operating cost under nonregulated economics 87

41 Effect of power unit size on annual operating cost under cooperative economics 87

42 Effect of power unit size on average annual operating cost under regulated economics 88

43 Effect of power unit size on operating cost/ton of fertilizer under regulated economics 88

44 Effect of power unit size on operating cost/ton of coal under regulated economics 89

45 Effect of sulfur content of coal on annual operating cost under cooperative economics 89

46 Effect of sulfur content of coal on unit operating cost under cooperative economics 90

47 Effect of process operating time on annual operating cost (process A) 90

48 Effect of process operating time on annual operating cost (process B) 91

49 Effect of process operating time on annual operating cost (process C) 91

50 Effect of process operating time on unit operating cost 92

Page

51 Effect of credit for air pollution control on unit operating cost 92
52 Phosphoric acid plant locations 94
53 Central U. S. inland waterway system 95
54 Ammonia plant locations 96
55 Major ammonia pipelines 96
56 Bulk blend fertilizer plants by counties (1968) . . . 97
57 Fertilizer use pattern in the United States 99
58 U. S. nitrogen fertilizer consumption by regions (1945-1968) 100
59 Approximate location of major thermal power plants 101
60 Substitution of byproduct 28-14-0 for ammonium nitrate and 18-46-0 at specified competitive price conditions 104
61 Average return to manufacturing (ARM) and average length of haul (ALH) for 28-14-0 (based on delivered price competitive with ammonium nitrate) 105
62 Average return to manufacturing (ARM) and average length of haul (ALH) for 26-19-0 (based on delivered price competitive with ammonium nitrate). 105
63 Average return to manufacturing (ARM) and average length of haul (ALH) for 19-14-0 (based on delivered price competitive with ammonium nitrate). 106
64 Average return to manufacturing (ARM) and average length of haul (ALH) for 21-0-0 (based on delivered price competitive with ammonium nitrate) 106
65 Expected market boundaries for 28-14-0 and 19-14-0 for ammonium nitrate competition and a 500-mw plant 107
66 Ultimate competitive market boundaries for 28-14-0 and 19-14-0 for diammonium phosphate competition and a 500-mw plant 107
67 Effect of power unit size on payout period for nonregulated economics 115
68 Effect of power unit size on interest rate of return for nonregulated economics 115

Page

69 Effect of power unit size on payout period for cooperative venture 116
70 Effect of power unit size on interest rate of return for cooperative venture 116
71 Effect of credit for air pollution control on payout period 117
72 Effect of credit for air pollution control on interest rate of return 117
73 Effect of sulfur content of coal on payout period 118
74 Effect of sulfur content of coal on interest rate of return 118
75 Effect of operating time on payout period 119
76 Effect of operating time on interest rate of return 119
77 Effect of variations in net sales revenue on payout period (process A) 120
78 Effect of variations in net sales revenue on payout period (process B) 120
79 Effect of variation in net sales revenue on interest rate of return (process A) 121
80 Effect of variation in net sales revenue on interest rate of return (process B) 121
81 Effect of recovery unit life on interest rate of return 122
82 Effect of power unit size on cumulative present worth of annual net increase or decrease in cost of power consumers 122
83 Effect of sulfur content of coal on cumulative present worth of annual net increase or decrease in cost of power to consumers 123
84 Effect of operating time on present worth of the cumulative net increase or decrease in cost of power to consumers 123
85 Effect of variation in net sales revenue on cumulative present worth of the annual net increase or decrease in cost of power to consumers (process A) 124
86 Effect of variation in net sales revenue on cumulative present worth of the annual net increase or decrease in cost of power to consumers (process B) 125

SUMMARY

The present study is the third in a series being carried out by TVA for NAPCA on methods for removing sulfur oxides from power plant stack gases. The first two were concerned with use of lime or limestone as absorbents, which convert the gaseous sulfur oxides to solid compounds (calcium sulfite and calcium sulfate) that are discarded. In the processes evaluated in the present study, the oxides are recovered as intermediates for production of fertilizer products that can be sold to offset, at least partially, the cost of operation.

Processes that utilize recovered sulfur products are potentially superior to the throwaway type because of the possibility that the sales revenue will reduce the cost of sulfur oxide control. On the other hand, recovery requires much more investment, the necessity for product sale complicates power plant operation, and the very large amount of end products would have an upsetting effect on existing markets.

Many processes have been proposed for sulfur oxide recovery and some have been studied on a fairly large scale. In several instances claims have been made that a particular method will "break even" or even show a substantial profit. Such optimistic economic projections are not warranted, however, unless they are based on a thorough conceptual design and cost study that takes into account all the complexities of incorporating a major chemical manufacturing operation into a power plant. This is the purpose of the current NAPCA-TVA series. The most promising processes are selected and each subjected to a detailed study in which the best design is developed from the available data, capital and operating costs are estimated on a uniform basis, a market survey is made so that sales revenue can be estimated, total cash flow is related to economic promise, and needed research and development is identified.

Scrubbing with aqueous ammonia solutions, the subject of the present study, is one of the simplest and most economical ways of getting the sulfur oxides out of the gas. Ammonia is relatively cheap, has a high affinity for sulfur oxides, and can be allowed to go on into the product because it is a good fertilizer material, worth more in the solid form than as the original liquefied gas. However, since use of ammonia requires a wet-scrubbing operation—as in the limestone - wet scrubbing method—the gas is cooled and reheating is required.

Scrubbing with ammonia gives a scrubber effluent solution containing ammonium sulfite [$(NH_4)_2SO_3$] and ammonium bisulfite (NH_4HSO_3); the main problem is how best to convert these to useful products. There are many ways to do this, too many to be evaluated in a single study. Ammonia scrubbing can be regarded as a general field of sulfur oxide recovery technology, with many separate "processes" for converting the scrubber solution to something usable.

The approach selected for the present evaluation is to oxidize the sulfite to sulfate, a more useful form. The product is ammonium sulfate [$(NH_4)_2SO_4$], a material that can be sold (as fertilizer) but does not command a very large market. It would be better to use the ammonium sulfate as an intermediate in making some other fertilizer that has a greater market potential. There are three major possibilities for this, all of which are evaluated in this report.

Process A—Direct oxidation of the scrubber solution with air to give ammonium sulfate solution, which is then used to precipitate calcium in a nitric phosphate process. In the latter, phosphate rock (calcium phosphate ore) is dissolved in nitric acid, the ammonium sulfate solution is added to precipitate the calcium from the ore as calcium sulfate, and the resulting solution of ammonium nitrate and phosphoric acid is separated from the calcium sulfate and treated with ammonia to give a solid ammonium nitrate-ammonium phosphate fertilizer containing about 28% nitrogen and 14% phosphate (as P_2O_5). The calcium sulfate is discarded.

Process B—The scrubber solution is treated with sulfuric acid, which joins with the ammonia to give ammonium sulfate. Sulfur dioxide freed by decomposition of the sulfites is evolved and is converted to sulfuric acid in a standard acid plant. Part of the acid is used to acidify the scrubber solution and the remainder is used to supplement the nitric acid in the nitric phosphate process. The ammonium sulfate solution is used in the same way as in process A. The process has the advantage that using sulfuric acid in the nitric phosphate operation gives a more favorable nitrogen:phosphate ratio in the product (about 26% N and 19% P_2O_5).

Process C—The scrubber solution is oxidized as in process A, the ammonium sulfate is crystallized, the crystals are heated to convert them to ammonium bisulfate (NH_4HSO_4), and the bisulfate is used (in solution) to dissolve phosphate ore. Precipitated calcium sulfate is separated and discarded. The solution is finished as in process A, giving a product containing about 20% N and 15% P_2O_5. The main advantage, as compared with process A, is that no nitric acid is required and therefore a more favorable nitrogen:phosphorus ratio is obtained.

Study Assumptions

Recovery process economics depend on several factors, including sulfur content of the coal, power plant size, operating factor, and power plant status (new vs existing).

It was necessary to assume a single combination of conditions as a base case for the conceptual design. In the cost estimates, the effect of variation in the major parameters was evaluated. The basic conditions assumed are as follows:

Power unit size, mw	500
Sulfur content of coal, %	3.5
Ash content of coal, %	12
Degree of SO_2 removal, %	90
Degree of dust removal, %	99.5
Power plant status	New
Capacity factor, % of nameplate rating	
First to 10th yr	80
10th to 15th yr	57
15th to 20th yr	40
20th to 35th yr	17
Average over life	43
Product storage capacity, days	90
Stack gas reheat temperature, °F	250
Plant location	Midwest

Process Equipment

The scrubber is one of the most expensive units in a recovery system because it must handle the full flow of gas (over 100,000 tons/day for a 1000-mw boiler) whereas the solution treatment and fertilizer units handle a much lower throughput. Based on a study and analysis of the data available on ammonia scrubbing, the scrubber design selected was the impingement version of the crossflow sieve tray type. This type appears to give the lowest pressure drop for the required degree of sulfur dioxide removal and also has good dust collection efficiency.

Stagewise scrubbing will be necessary to minimize ammonia loss in all processes and to maximize bisulfite formation in process B (for maximum yield of sulfuric acid). The number of stages required was calculated to be three for processes A and C and four for process B. In addition, the design includes a prescrubbing stage (in the same scrubber tower) to remove the dust. Four scrubbers, each handling 333,000 acfm at 118° F and each 20 x 40 x 27 ft high, are required for the 500-mw boiler unit.

Reheating is accomplished by a closed liquid loop that transfers heat from the gas before the scrubber to the scrubber exit gas. Estimates made in the previous study on limestone - wet scrubbing indicated this to be the most economical of several reheating methods considered.

Oxidation of the scrubber solution in processes A and C is carried out in equipment that has been proven in large installations in Japan. Detailed design information can be obtained under license. The acidification step in process B has also been tested on a large scale, by Cominco in Trail, B. C.

The fertilizer step in processes A and B has been tested in a TVA pilot plant and on a large scale in Europe. Hence all steps of these methods are relatively well established and detailed design information can be readily obtained, which is not true for most of the recovery methods that have been proposed. For process C, however, only limited small-scale data are available.

Economic Considerations

Evaluation of recovery processes brings in factors such as product marketability and price, profit margin, and projected financial promise, all of which make the analysis much more difficult than for the throwaway methods. It would be desirable, of course, that the methods show promise of a net profit, but this is not essential because recovery should be preferable to throwaway, even at a net loss, as long as the loss is lower than the cost by throwaway. Thus the cost of limestone - wet scrubbing becomes the basic criterion for comparison. This was calculated for the various combinations of variables in the current study and used in evaluating the recovery processes.

The basis on which the recovery project is financed is a major consideration in evaluating economic promise and acceptability. Since power companies generally are not familiar with producing and marketing anything except power, there would be some advantage if a fertilizer company operated the recovery process and marketed the fertilizer products. For a private, unregulated company to enter into such an activity, however, the project would have to be promising enough to attract the necessary capital from investors. It is difficult to say how much promise would be required because this varies with the situation. It is generally considered that the projected cash flow (depreciation plus profit after taxes) should pay out the investment in about 5 yrs, or, on another basis which takes into account the time value of money, the interest rate of return[1] should be about 15% (to recover both investment and a reasonable return on investment). For the relatively high investment required in sulfur oxide recovery processes, this is a major hurdle.

If the power company finances the project, the situation is entirely different. The investment would be part of the total power plant investment, on which the company is allowed to earn what the regulatory authority regards as a reasonable return on investment. If sulfur oxide removal, either by a throwaway or recovery method, were to increase operating cost, then the price of power to the power consumers presumably could be raised to offset the extra cost. Sulfur oxide removal (even by recovery), dust collection, and cooling water recycling can all be considered as necessary to production of power, just as is the boiler operation, and the costs therefore should be passed on to the power consumer. It is true that rate increases are often contested and delayed, and that the full adjustment may not be allowed, so that the power company has considerable incentive to avoid extra investment and operating cost. In general, however, the power industry has a more-or-less guaranteed profit. For this reason, there is little risk and capital can be attracted at the regulated rate of return.

---

[1] Interest rate at which present worth of the annual cash flow over the life of the plant is equal to the investment.

Thus as a practical matter (but within some limits), loss from operation of a sulfur oxide recovery unit can be passed on to the power consumer. The main concern is the trouble and delay in getting a rate increase. Another consideration, however, is that neither power producer nor regulatory authority has any reason to favor recovery if it loses more money than limestone - wet scrubbing. Therefore, for evaluation of the regulated financing basis the present worth of expenditures over the life of the plant must be compared, for each recovery method, with present worth for limestone - wet scrubbing cost.

Because of the large product volumes involved, sulfur oxide recovery may have a major upsetting effect on markets for competing products. For fertilizer industry financing this is justifiable because each product should have the right to find its place on the economic ladder. For power company financing, however, there is the somewhat artificial factor that financial viability comes from sale of power rather than sale of recovery product and that the latter therefore could be dumped on the market at a price not in accordance with the intrinsic economics. The effect of this factor on the acceptability of regulated economics for recovery processes is not clear at the present time.

Capital Required

Investment under various combinations of conditions are given for process A in table S-1. Investment for processes B and C ($37.5 and $31/kw for base case) were somewhat lower than for process A. However, this is not significant as process A makes more fertilizer product because of the nature of the process; the production rates in tons/hr are 43, 33, and 19 for A, B, and C. Profitability/unit of investment is the only valid method for comparing the processes.

The investment required is relatively high as compared with other recovery methods. However, a finished product is made rather than an intermediate such as sulfur or sulfuric acid; about 75% of the investment is in the fertilizer part of the plant. Again, return/unit of investment is the important criterion.

Profitability

A major consideration in profitability is net sales price of the product. A market survey for the fertilizer products resulted in the following conclusions.

1. The plant should be located in the Midwest.
2. Sales price should be set to compete with ammonium nitrate rather than diammonium phosphate. This involves a relatively large sales area and therefore high shipping cost but gives more net revenue.
3. Expected returns to manufacturing range from $33.40-39.50/ton of fertilizer.
4. The market is not large enough to support more than about three 500-mw plants in the midwestern part of the country.

Fertilizer Participation—Based on the projected revenue, process A gives the payout periods and interest rates of return shown in table S-2. The results are unpromising and indicate strongly that, on their own, the processes are not profitable enough to attract capital. It is conceivable, however, that the power producer would be willing to pay the fertilizer company a fee for the service of abating pollution, since otherwise the power plant would incur the heavy cost of a throwaway process. Table S-3 shows the economics on the basis of a payment to the fertilizer company equivalent to the cost of limestone - wet scrubbing. With this maximum service charge for sulfur oxide control, the larger plant sizes become attractive but the 500-mw base case remains questionable.

Process B economics are not quite as good as for process A but the difference probably is not significant. For

Table S-1. Capital Requirements for Process A

Conditions	Capital, $/kw of power capacity
Base case (500-mw, new power unit, 3.5% sulfur in coal, 43% average capacity factor, reheat to 250° F)	41
Exceptions to base case	
Existing power unit	45
5% sulfur	50
Reheat to 175° F	38
1,000 mw	33

Table S-2. Profitability of Process A

Conditions	Payout, yr	Interest rate of return, %
Base case (500-mw, new power unit, 3.5% sulfur in coal, 43% average capacity factor, reheat to 250° F	8.7	5.7
Exceptions to base case		
Existing power unit	9.8	1.4
5% sulfur	6.6	11.4
Reheat to 175° F	7.9	7.3
1,000 mw	6.4	12.0

example, payout and interest rate of return for the base case (with payment of pollution abatement fee to the fertilizer company) are 6.3 yrs and 12.5% as compared with 6.1 yrs and 13.0% for process A.

The process technology for process C is not as well defined as for processes A and B. Therefore, the accuracy of estimates used in economic evaluation of this process is relatively low. However, the conclusion that process C economics are poor is valid. In most cases, the cash flow is out rather than in and the investment does not pay out at all, even with income from the pollution payment.

A cooperative venture was also evaluated, with the power company financing and operating the scrubbers and the fertilizer company producing the fertilizer. In comparison with the all-fertilizer company approach, the economics are not significantly different. The cooperative project has a small advantage for the largest plant sizes.

Power Company Economics—If the power company finances the complete recovery installation and the investment is incorporated in the rate base, the situation is considerably different. The main question then is whether or not the recovery process saves any money as compared with limestone - wet scrubbing.

A comparison of the two methods is given in table S-4. The values given are present worth of the net annual costs over the life of the power plant; this basis was used because one system may be better in one particular yr and the reverse in some other yr. Thus the values given represent the total bill in current money for sulfur oxide control over the life of the power plant.

The costs for the two methods (at 3.5% S) are about the same at 500 mw; above this, recovery becomes increasingly preferable to limestone - wet scrubbing. The same effect can be obtained by increasing the sulfur content of the coal.

The economics for both power and fertilizer financing are quite sensitive to projected sales revenue. For example, an increase of 10% over the revenue projected would reduce the equal-cost size to about 300 mw, and 10% less would increase it to about 850 mw.

Table S-3. Profitability of Process A with Supplementary Income as Payment for Pollution Abatement

Conditions	Payout, yr	Interest rate of return, %
Base case (500-mw, new power unit, 3.5% sulfur in coal, 43% average capacity factor, reheat to 250° F)	6.1	13.0
Exceptions to base case		
Existing power unit	6.4	11.0
5% sulfur	5.0	17.4
Reheat to 175° F	5.9	13.7
1,000 mw	4.9	17.9

Table S-4. Cost of Recovery vs Limestone - Wet Scrubbing Under Power Company Economics

	Present worth of annual net costs,[a] $ millions	
Conditions	Recovery (Process A)	Limestone - wet scrubbing
Base case (500-mw, new power unit, 3.5% sulfur in coal, 43% average capacity factor, reheat to 250° F)	17.2	16.8
Exceptions to base case		
Existing power unit	22.4	16.9
5% sulfur	5.3	19.7
Reheat to 175° F	14.2	14.2
200 mw	19.4	7.2
1,000 mw	4.6	26.5

[a] Over plant life of 35 yrs.

Conclusions and Recommendations

Conclusions resulting from the present study can be summarized as follows:

1. Ammonia scrubbing and production of phosphate fertilizer has promise, under certain conditions, as a method for recovering sulfur oxides from stack gases.
2. The main economic factors are product volume (depending on power plant size and S content of coal), net sales revenue, and basis of financing.
3. Private industry participation in financing and operation appears unlikely because of the high projected cash flow necessary to attract capital. There is a net profit for plants about 500 mw and larger but it is not large enough to attract investment except perhaps under special conditions. The situation is improved if there is supplemental income in the form of a payment for the service of sulfur oxide control; in this case the larger product volumes (e.g., 1000 mw at 3.5% S in coal or 500 mw at 5% S) give a projected total income adequate for financing.
4. The economics under power industry financing are more promising. For plants 500-600 mw and larger in size the recovery method is favored over limestone - wet scrubbing because there is less deficit passed on to the power consumer after payment to investors of the regulated return on investment.
5. Only a few recovery installations of this type can be accommodated by the fertilizer market.
6. It may be possible to improve the economics by (1) increasing the lifetime capacity factor, (2) reducing the degree of gas reheat, and (3) development of new departures that may reduce investment and operating cost.

Further data on design and operation of the processes are needed to refine the estimates. Some needed information will be obtained in the current NAPCA-TVA pilot plant project on ammonia scrubbing, in which the parameters involved in the scrubbing step will be studied intensively. It is recommended in addition that research be done aimed at eliminating the oxidation step in process A. No further work on process C is recommended unless fertilizer research organizations find ways to improve the fertilizer sections of the process. Finally, conceptual design and cost studies should be carried out on other ways of recovering sulfur values from the scrubber solution.

INTRODUCTION

This report presents the third in a series of conceptual design and cost studies mady by the Tennessee Valley Authority (TVA) for the National Air Pollution Control Administration (NAPCA) on methods for removing or recovering sulfur oxides from power plant stack gases. The first two covered use of limestone as a sorbent for sulfur oxides, in dry and wet processes respectively; in both cases, the sulfur oxides removed from the gas are discarded as calcium sulfate or sulfite. The present report is concerned with the use of ammonia as the absorbent, in processes that recover a useful product which can be sold to offset, at least partially, the cost of operation.

Ammonia is an expensive absorbent as compared with limestone and therefore must be recovered either for recycle (regenerable process) or as a constituent of the product (nonregenerable process). The present study is restricted to those variations of the nonregenerable process in which ammonium sulfate is obtained as an intermediate product and is then used as a raw material in production of a multinutrient fertilizer. It is planned to evaluate other variations, of both the nonregenerative and regenerative processes, in future studies.

The need to remove sulfur oxides from power plant stack gases has been well documented in numerous reports and publications. Sulfur dioxide is generally regarded as the most serious of the several gaseous pollutants, mainly because of the tremendous quantities emitted from smelters, power plants, and industrial boilers. It has been estimated that about 30 million tons of sulfur dioxide is emitted to the atmosphere annually in the United States alone, and that of this amount power plants account for about half. Emission can be reduced by using low-sulfur fuel, either low in the natural state or processed to remove sulfur, or the polluting effect can be reduced by dispersion from tall stacks. These approaches have major drawbacks, however, to the extent that treatment of the stack gas to remove the pollutants may be preferable.

Recovery of the sulfur oxides in a useful form is obviously desirable, both to give some income to help offset the removal cost and also to conserve a valuable national resource. Moreover, a new source of sulfur is needed for the fertilizer industry, a major consumer of sulfuric acid, because the usual sources are being depleted. Thus the combination of pollution abatement, conservation of a natural resource, and meeting the needs of the fertilizer industry is a major incentive to sulfur dioxide recovery. Unfortunately, the low sulfur dioxide content in the stack gas (0.2-0.3%), plus unfavorable factors in power plant operation, make recovery an extremely difficult operation to carry out at acceptable cost.

In the previous two studies in this series, it was assumed that recovery would not be attempted and that the product would be discarded; as a result the process was simplified, costs for equipment and operation were reduced, and other advantages not amenable to cost estimating were obtained. The removal cost was a complete loss, of course, since there was no income from product sale, but the estimated cost was low enough (typically $0.65-1.00/ton of coal burned) to be acceptable. The question in regard to recovery processes is whether the economics, even after income from product sale, will be any better. The purpose in this and the further design studies on recovery methods will be to answer this question

In addition to the undesirable composition of the gas, low in sulfur dioxide and high in fly ash and moisture, the very large amount of sulfur involved is a problem in applying recovery to modern, large-boiler, multiunit power plants. Pertinent data for a 1000-megawatt (mw) boiler are as follows:

Coal burned, ton/day (100% capacity factor)	9,000
Typical sulfur content of coal, %	3.5
Sulfur emitted, % of S in coal	92
Sulfur emitted/day as tons of	
Sulfur dioxide	578
Sulfuric acid	885
Sulfur dioxide content in gas, volume %	0.22
Gas flow	
Acfm	2.0×10^6
Ton/day	110,000
Dust in gas, ton/day	810
Moisture in gas, ton/day	8,600

For a 3000-mw base station, which power plant size is approaching, the equivalent of 2,660 tons of sulfuric acid would be produced/day. Selling this much acid, or any other product except perhaps elemental sulfur, from one point is a major problem.

Quantity becomes a problem also if recovery is considered as a general, country-wide solution to the sulfur oxide control problem. The large tonnage of sulfur-containing materials produced would have a major impact on the market structure for such products. Data pertinent to this problem are are as follows (estimated data for the year 1970):

	Tons/yr
Sulfur emitted from utility power plants in the U. S. (40)	10,000,000
Sulfur consumed in the U. S. (62)	11,000,000
Power plant sulfur emission expressed as sulfuric acid	30,700,000
Sulfuric acid consumed in the U. S. (62)	30,600,000
Sulfuric acid consumed by the U. S. fertilizer industry (62)	18,500,000

It would not be expected that all plants would be equipped with sulfur recovery processes, and the processes would not recover all the sulfur from the gas. Nevertheless, recovery of even one-half of that emitted would present a major marketing problem and would seriously affect the economic situation of companies now making the sulfur products in question.

A great many sulfur oxide recovery methods have been proposed—literally hundreds if variations and untried processes are included in the count; the problem has been a favorite subject for researchers for several decades. The field is so complicated that NAPCA has contracted for a group of area surveys to sort out the methods, organize them into a manageable classification, and evaluate them on a preliminary basis. The subjects of these surveys make a convenient general classification scheme.

1. Scrubbing with aqueous salt solutions.
2. Sorption by metal oxides.
3. Catalytic oxidation of sulfur dioxide to sulfur trioxide.
4. Sorption by inorganic solids other than oxides.
5. Reduction of sulfur dioxide to sulfur.
6. Sorption by inorganic liquids.
7. Sorption by organic solids.
8. Sorption by organic liquids.
9. Separation of sulfur dioxide by physical methods.

Of these, the first three have received major attention. Large semiworks-scale units have been built to demonstrate processes falling within each of the three classes. It is not appropriate here to review these processes or to evaluate the three general types against each other. It can be said, however, that each has shown some promise, each has major disadvantages, and none has been shown conclusively to be better than the others.

One of the main disadvantages in aqueous salt solution scrubbing, the class into which the present study falls, is that the aqueous solution cools the gas—to a temperature as low as 125° F—and therefore a good part of the thermal lift in the gas plume leaving the stack is lost. As a result the plume may come back to the ground sooner than otherwise, without the normal degree of dilution by ambient air, and thereby increase the problem from pollutants such as nitrogen oxides that it still contains. The cost of reheating the gas before emission was estimated in the limestone - wet scrubbing report; the cost is significant but may be no more a handicap than those of different nature found in the other process types.

Countering this disadvantage of plume cooling, aqueous solution scrubbing has the advantages of high absorption efficiency and simplified handling of absorbent both in scrubbing and regeneration. (Nonaqueous liquids would give the same advantages but have some major drawbacks.) There are also advantages over use of solid sorbents; granular solids may deteriorate structurally, and fine solids, since they travel with the gas, may require large vessels or multicycling to get adequate retention time and special equipment to get adequate separation from the gas.

Among aqueous scrubbing processes, use of an ammoniacal salt solution has received the most attention. The ammonium cation is an effective reactant, the cost of ammonia makeup is low, and there are several methods for treating the scrubber effluent to recover the sulfur that may have promise. Recovery of the sulfur as an ammonium compound for sale or further use is the simplest method for treating the scrubber effluent. The regenerative methods require more processing steps and are subject to process complications. A pilot plant program is being carried out by TVA for NAPCA to provide information for future evaluation of these methods.

Sodium and potassium salt solutions have been studied also but to a lesser extent. It is planned to extend the pilot plant program to cover the potassium system as the basis for a later design and cost study.

PROCESS VARIATIONS IN AMMONIA SCRUBBING

Recovery of sulfur oxides by ammonia scrubbing involves many possibilities and complications, both in regard to the scrubbing step and to treatment or use of the loaded absorbent. Several flowsheets can be drawn up even for one particular end product and there are several products that can be made. To clarify the subject, an outline of the process variations is desirable.

Scrubber Design and Operation

When ammonia is first introduced into the scrubber system it can react as follows:

$$NH_3 + H_2O + SO_2 \rightleftharpoons \underset{\text{Ammonium bisulfite}}{NH_4HSO_3} \qquad (1)$$

$$2NH_3 + 2H_2O + SO_2 \rightleftharpoons \underset{\text{Ammonium sulfite}}{(NH_4)_2SO_3} \qquad (2)$$

Process considerations, however, require recycling of part or all of the scrubber liquor, either from a regeneration step or because recycling at the scrubber is necessary for good absorption. In either case, operation does not continue long until ammonium sulfite becomes the principal scrubbing agent.

$$(NH_4)_2SO_3 + SO_2 + H_2O \rightarrow 2NH_4HSO_3 \qquad (3)$$

Complete reaction to bisulfite is not feasible, however, because the pH would be reduced to so low a level that sulfur dioxide could not be removed effectively. In practice the pH is adjusted to give the best balance between sulfur dioxide leakage at low pH and ammonia loss at high pH. To get the best results in this respect, stepwise scrubbing can be employed, with relatively high pH in a first or second stage (preferably the second stage; see below) and lower pH (plus more dilute solution) in a cleanup stage to minimize ammonia loss.

Hence the scrubber effluent contains both ammonium sulfite and bisulfite, in a ratio determined by the way in which the scrubber is designed and operated. It also contains ammonium sulfate because some oxidation of sulfite by oxygen in the stack gas is unavoidable; moreover, the entering gas contains a small amount of sulfur trioxide that reacts with ammonia to form ammonium sulfate.

For some of the nonregenerative processes, the composition of the scrubber solution is not critical; the scrubber function is only to remove sulfur dioxide while preventing loss of ammonia. Conversion of ammonia and sulfur dioxide to ammonium sulfite (equation 2) would be desirable except that at the high pH (8.0) ammonia loss would be high. For processes that require ammonium sulfate as an intermediate or final product, formation of sulfate would not be a problem and in fact should be promoted, as much as possible without interfering with absorption, to reduce the requirement for oxidation of sulfite to sulfate in a subsequent step.

For regenerative processes (and some of the nonregenerative type), it is desirable to have as high a bisulfite:sulfite ratio and as low a concentration of sulfate as possible. Bisulfite forms more readily when the first stage of scrubbing is operated at relatively low pH (about 4), thereby increasing the sulfur dioxide:ammonia ratio. Scrubbing efficiency is reduced but the succeeding stage or stages, operated at higher pH, finish the job.

Research by previous investigators indicate that sulfate formation can be minimized in several ways, including (1) use of oxidation inhibitors, (2) removal of dust before scrubbing (to avoid any catalytic effect either from the absorptive surface or the metal compounds present), (3) use of nonmetal materials in scrubber construction (also to avoid catalysis), and (4) minimizing oxygen absorption by selection of scrubber design and by operating at as high solution concentration as possible. However, the available data is not adequate for evaluating these effects.

Hence the scrubber effluent is a solution of ammonium sulfite, ammonium bisulfite, and ammonium sulfate. A typical liquor composition, (41) for a process requiring high bisulfite:sulfite ratio, is as follows:

	g/l
Ammonia	95
Sulfur, total	133
Sulfur present in bisulfite form	87
Sulfur present in sulfite form	23
Sulfur present in sulfate form	23
pH	5.9

Treatment of Scrubber Effluent

The ammonia scrubbing step removes the sulfur dioxide from the gas efficiently and produces it as a concentrated solution of sulfite, bisulfite, and sulfate. The sulfite and bisulfite are not useful products so it is necessary to convert them to something else, and to recover the ammonia for recycling unless it goes on with the product. Numerous methods for conversion and recovery have been proposed and some have been tested. Those that appear to have some promise will be summarized.

In order to simplify the presentation, the various methods for treating the scrubber effluent solution will be divided into five principal classes.

1. *Stripping*—The ammonium bisulfite is an unstable compound and will produce a relatively high vapor pressure if heated even to a level of only 50° F or so above the scrubbing temperature. Moreover, the sulfur dioxide partial pressure is much higher than for the ammonia, so that passing the gas through a condenser to condense the ammonia as ammonium sulfite will produce a stream of sulfur dioxide and water vapor essentially free of ammonia. The stripped solution and the condensate are recycled to the scrubber, and the sulfur dioxide is converted either to sulfuric acid or elemental sulfur as the final product (figure 1).

Feasibility of the stripping method depends largely on the amount of bisulfite in the scrubber effluent solution. Ammonium sulfite does not contribute because even if it were decomposed all the sulfur dioxide would recondense with the ammonia. Therefore it is necessary to design and operate the scrubber to give as high a bisulfite to sulfite ratio as can be obtained without incurring offsetting adverse effects. This is a difficult problem as will be discussed later.

2. *Acidification*—Since sulfurous acid (H_2SO_3) is a weak acid, any strong acid added to the scrubber effluent will capture the ammonia and release sulfur dioxide from the sulfite and bisulfite. This method gives two products: (1) either sulfuric acid or elemental sulfur made from the evolved sulfur dioxide and (2) the ammonium salt of the added acid. Since sulfuric, nitric, and phosphoric are the most appropriate acids to use, the coproducts are ammonium sulfate, ammonium nitrate, and ammonium phosphate respectively (figure 2).

If sulfuric acid is used, an obvious source of the acid is the sulfur dioxide evolved, converted to sulfuric acid in an acid plant installed as part of the recovery installation. More acid will be produced than needed for effluent acidification, so that there is some net production of sulfuric acid for sale. The amount depends on the content of bisulfite in the scrubber effluent, as each mole of bisulfite produces one mole of sulfur dioxide in excess of that required to make the sulfuric acid for recycling, whereas all the sulfur dioxide evolved from ammonium sulfite must be recycled.

$$2NH_4HSO_3 + H_2SO_4 \rightarrow (NH_4)_2SO_4 + 2SO_2 + 2H_2O \quad (4)$$

$$(NH_4)_2SO_3 + H_2SO_4 \rightarrow (NH_4)_2SO_4 + SO_2 + H_2O \quad (5)$$

Thus to maximize production of sulfuric acid, the scrubber should be designed and operated for high bisulfite; if ammonium sulfate is preferred then operation to give sulfite is indicated. In most situations sulfuric acid is the more desirable of the two products.

3. *Oxidation*—If ammonium sulfate is the desired product, the simpler procedure can be used of oxidizing sulfite directly to sulfate while still in solution. The scrubber effluent is reacted with oxygen (ordinarily supplied as air) under pressure to convert ammonium sulfite

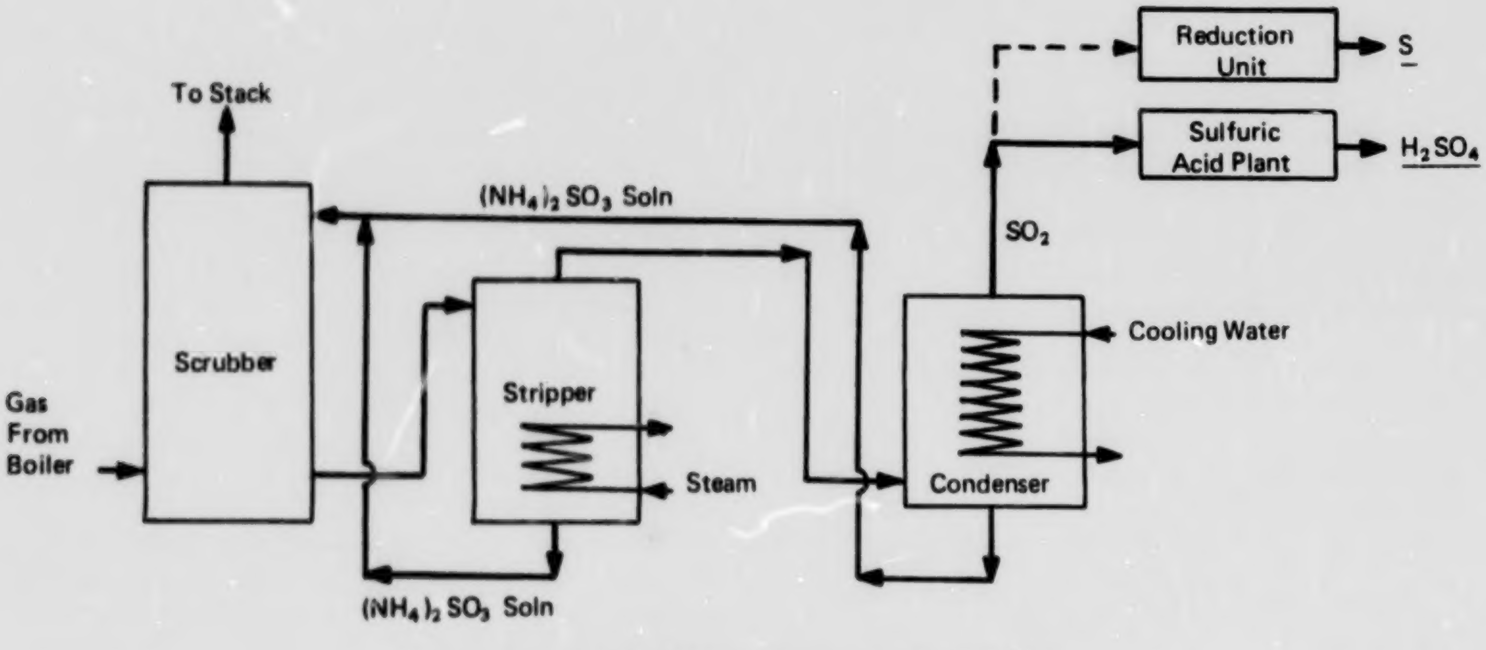


Figure 1. Ammonia Scrubbing: Regeneration by Stripping

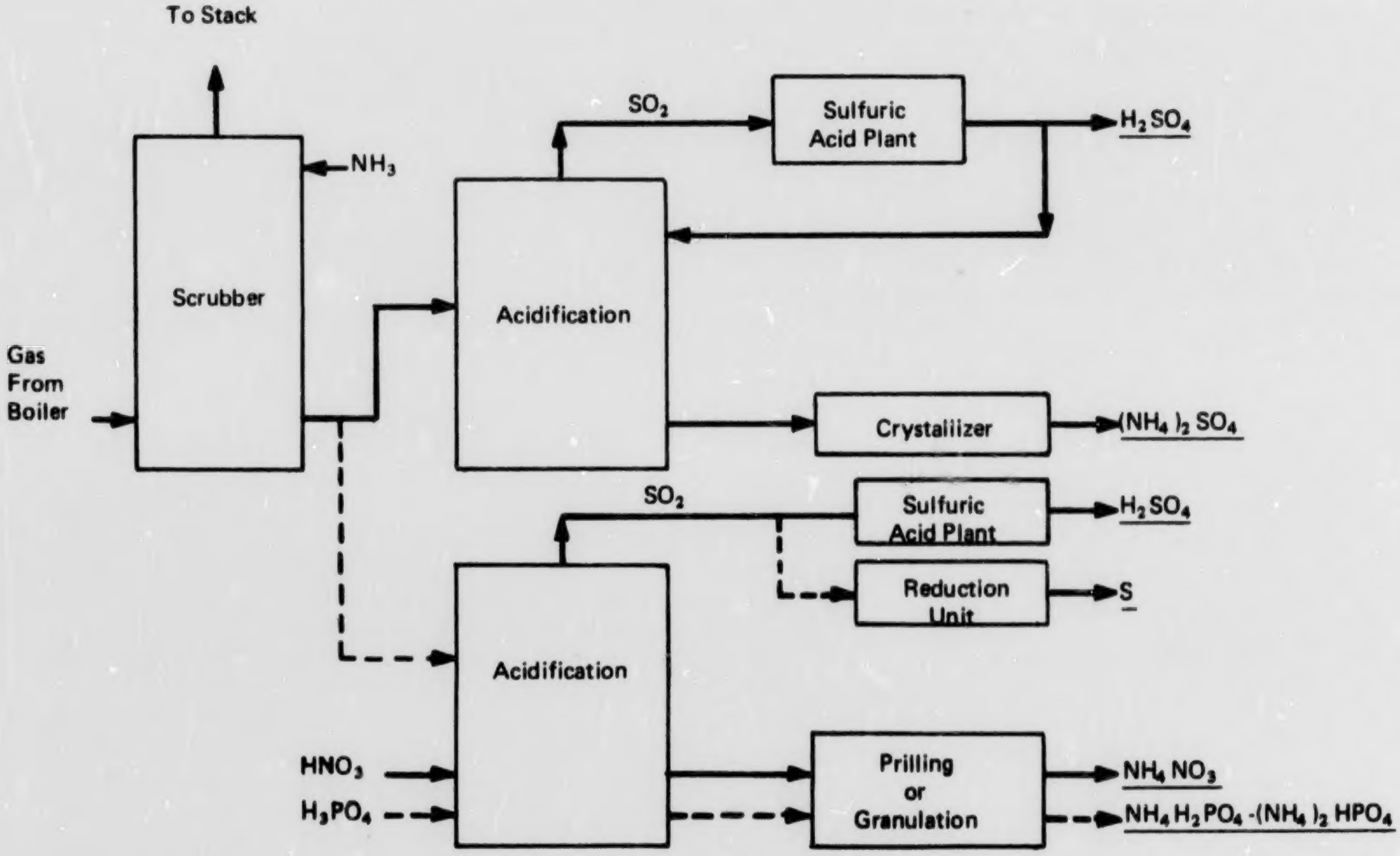

To Stack
Scrubber
NH_3
Gas From Boiler
SO_2
Sulfuric Acid Plant
H_2SO_4
Acidification
Crystallizer
$(NH_4)_2SO_4$
SO_2
Sulfuric Acid Plant
H_2SO_4
Reduction Unit
S
Acidification
HNO_3
H_3PO_4
Prilling or Granulation
NH_4NO_3
$NH_4H_2PO_4$-$(NH_4)_2HPO_4$

Figure 2. Ammonia Scrubbing: Acidification of Effluent

to ammonium sulfate. The bisulfite is first converted to sulfite by addition of ammonia to the scrubber liquor before the oxidation step (figure 3). The only product is ammonium sulfate.

In this method both sulfite formation and oxidation in the scrubber are desirable, which simplifies the operation considerably.

4. *Autoclaving*—If ammonium bisulfite and sulfite are heated under pressure disproportionation takes place, that is, part of the material is oxidized and part is reduced. The reactions involved are complex and have been presented differently by various investigators. The following is an example but other reactions are known to take place.

$$2NH_4HSO_3 + (NH_4)_2SO_3 \xrightarrow[\text{press}]{\Delta} 2(NH_4)_2SO_4 + S + H_2O \quad (6)$$

The process has the advantage, in comparison with acidification, that sulfur rather than sulfuric acid is the coproduct with ammonium sulfate. Corrosion, however, appears to be a major problem.

5. *Precipitation*—Except for stripping, the above methods give an ammonium salt as the sole or coproduct whereas sulfur or sulfuric acid may be preferred from the marketing standpoint. As stripping requires a very large amount of heat and recirculation of large volumes of liquid between the scrubber and stripper, particularly for the lower ranges of sulfur dioxide content in the gas, alternate methods have been sought.

One approach is to add to the scrubber effluent some material that will precipitate the sulfur compounds in a nonammoniacal form; the precipitate is then separated and regenerated separately. In the analogous sodium sulfite scrubbing process, zinc oxide is the preferred material for

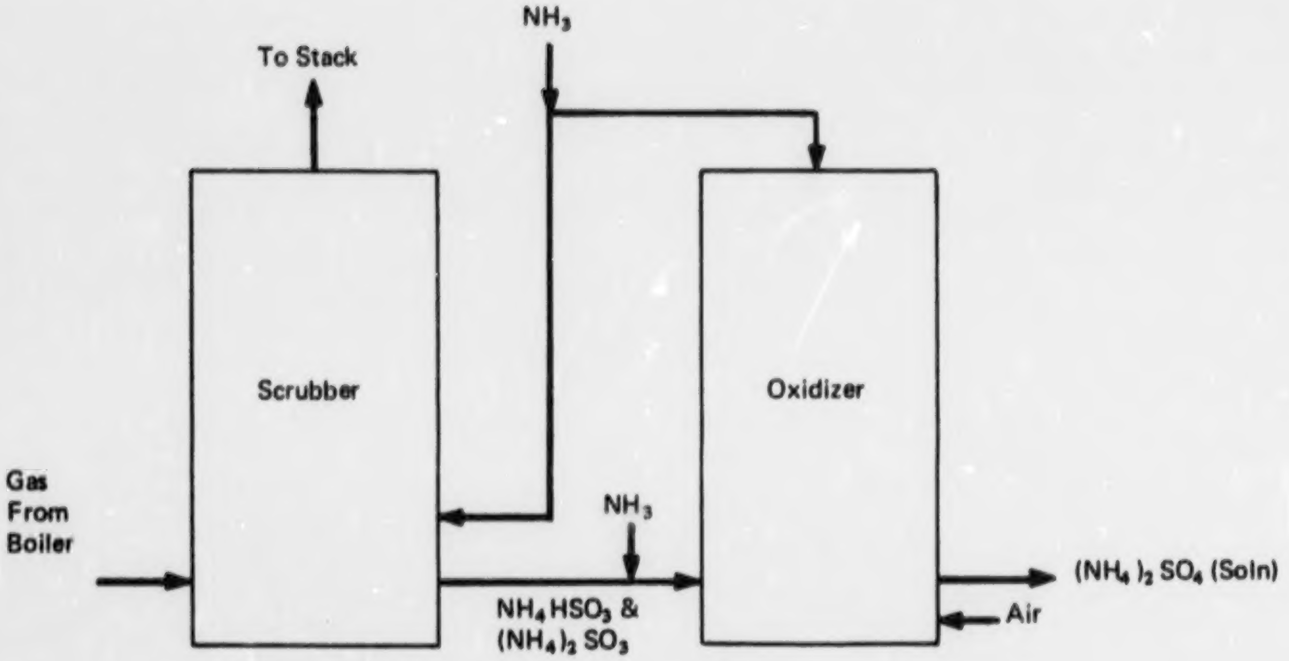


Figure 3. Ammonia Scrubbing: Production of Ammonium Sulfate

this reaction; it precipitates zinc sulfite, a compound that decomposes at about 500° F to give sulfur dioxide and regenerated zinc oxide – $ZnSO_3 \xrightarrow{\Delta} SO_2 + ZnO$ (figure 4). Presumably zinc oxide could be used also to precipitate zinc sulfite from ammonia scrubber effluent solution; however, the chemistry of the reaction does not seem to have been worked out.

The bisulfite to sulfite ratio in the scrubber liquor may not be important in this process but oxidation is undesirable because it results in formation of zinc sulfate, which has various undesirable process effects.

Another approach is to operate the scrubber at as high a solution concentration and bisulfite to sulfite ratio as possible and then add ammonia to the effluent solution. As sulfite is less soluble than bisulfite, conversion of bisulfite to sulfite by the ammoniation causes crystallization of sulfite. The separated crystals can be decomposed at relatively low temperature without the large amount of heat expended for water evaporation in the stripping process. The problem is that ammonia volatilizes as well as sulfur dioxide and the two are difficult to separate. Several methods for separation have been proposed but none have been studied enough even for preliminary evaluation.

Use of Ammonium Sulfate

Methods 2 and 3 discussed above for treating the scrubber effluent produce ammonium sulfate as either the sole product (method 3) or a coproduct (method 2). The methods have the advantages that no solution recycling, with the attending problems, are involved and that both have been investigated to a relatively advanced degree. The main drawback, for this country at least, is that ammonium sulfate is not a desirable product. Although it has been a leading fertilizer in the past, consumption is now somewhat static, the amount consumed is small relative to the potential production from power plants, and the sales price is relatively low. Moreover, the price structure is affected adversely by production of ammonium sulfate as a byproduct in other industries such as nylon and steel.

Hence it would be quite desirable to use the ammonium sulfate as an intermediate in making some other product. Production of phosphate fertilizers offers an opportunity for this, for ammonium sulfate can be used to tie up and remove calcium from phosphate ore (commonly called phosphate rock), an operation that must be carried out to make the phosphate usable as a fertilizer. There are two major possibilities for using ammonium sulfate in this way.

1. *Nitric Phosphate Fertilizer*—Various methods have been developed in the fertilizer industry for using nitric acid to dissolve phosphate rock so that it can then be converted to an effective fertilizer. Using nitric acid in this way eliminates the need for the sulfuric acid that is normally used, thereby gaining both process and economic advantages. The nitric acid method, however, introduces a problem because calcium nitrate, a very hygroscopic material, is formed and must either be removed or converted to a more acceptable material.

One of the methods that seems promising for dealing with the calcium nitrate problem is to treat the phosphate rock-nitric acid reaction slurry with ammonium sulfate, which reacts with the calcium nitrate to form soluble ammonium nitrate (an acceptable fertilizer material) and insoluble calcium sulfate. The precipitated calcium sulfate is then reacted with ammonia and carbon dioxide to convert it back to ammonium sulfate for recycling; the calcium carbonate also formed is discarded. The process is now under pilot plant development at TVA and shows promise as a way of reducing fertilizer cost.

If ammonium sulfate were already available from a power plant as the product of a sulfur oxide recovery operation, it could be used in the nitric phosphate process in place of the recycled ammonium sulfate. It would not be necessary then to go through the step of converting calcium sulfate to ammonium sulfate, and the cost of this conversion could be credited to the ammonia scrubbing process. The precipitated calcium sulfate would be discarded and the filtrate, containing ammonium nitrate and phosphoric acid, reacted with ammonia to give an ammonium phosphate-nitrate fertilizer.

A flowsheet for the process is shown in figure 5. An analogous system is employed in a European fertilizer plant, where byproduct ammonium sulfate from a caprolactam operation is used to precipitate calcium sulfate in a nitric phosphate plant of the type shown.

2. *Ammonium Phosphate-Sulfate Fertilizer*—In another approach, the ammonium sulfate is heated at about 700° F to convert it to ammonium bisulfate (NH_4HSO_4) and the evolved ammonia is recycled.

$$(NH_4)_2SO_4 \xrightarrow{\Delta} NH_4HSO_4 + NH_3\uparrow \qquad (7)$$

The ammonium bisulfate is acidic and therefore a solution of it can be used in place of sulfuric acid for dissolving phosphate rock. The resulting slurry would be filtered to remove calcium sulfate and then ammoniated to give ammonium phosphate-sulfate fertilizer. A flowsheet for such a system is shown in figure 6.

Ammonium sulfate can also be used as an intermediate or raw material in production of sulfuric acid or sulfur. Again there are two major possibilities.

1. *Use in Scrubber Solution Treatment*—Since ammonium bisulfate made by heating ammonium sulfate is acidic, it can be used in the acidification method discussed earlier for stripping sulfur dioxide from the scrubber effluent solution (figure 7).

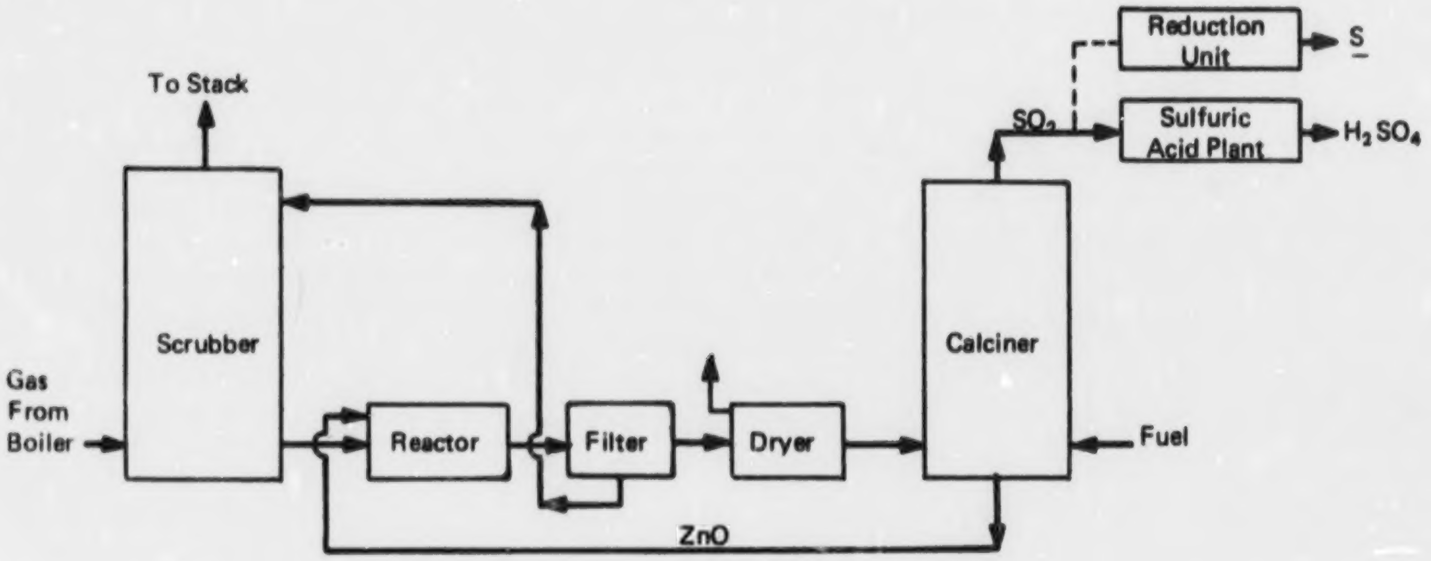


Figure 4. Ammonia Scrubbing: Precipitation (Zinc Oxide)

$$NH_4HSO_3 + NH_4HSO_4 \rightarrow (NH_4)_2SO_4 + SO_2\uparrow + H_2O \quad (8)$$

$$(NH_4)_2SO_3 + 2NH_4HSO_4 \rightarrow 2(NH_4)_2SO_4 + SO_2\uparrow + H_2O \quad (9)$$

$$(NH_4)_2SO_4 \xrightarrow{\Delta} NH_4HSO_4 + NH_3\uparrow \quad (10)$$

The advantage of this system is that the amount of ammonium sulfate ending up as final product is minimized. Only the sulfate resulting from oxidation before and in the scrubber goes into the product, whereas if sulfuric acid is the acidification agent as in the method described earlier, all the ammonium sulfite is converted to sulfate as well.

2. *Conversion to Sulfuric Acid*––The ammonium sulfate can also be converted back to ammonia and sulfuric acid. Reaction with zinc oxide at high temperature releases the ammonia and forms zinc sulfate, which can then be heated (at about 850° C) to regenerate the zinc oxide and give a rich stream of sulfur trioxide that can be absorbed directly to form sulfuric acid.

$$(NH_4)_2SO_4 + ZnO \rightarrow ZnSO_4 + NH_3\uparrow + H_2O \quad (11)$$

$$ZnSO_4 \xrightarrow{\Delta} ZnO + SO_3\uparrow \quad (12)$$

$$SO_3 + H_2O \xrightarrow{H_2SO_4} H_2SO_4 \quad (13)$$

This outline lists some of the many different process approaches that can be followed in using ammonia scrubbing for sulfur oxide recovery. Each of them could be the subject of a full design and cost study. To narrow the present study down to a manageable size, only those uses of ammonium sulfate that give a phosphate fertilizer will be considered. It is planned to cover some of the other possibilities in forthcoming studies.

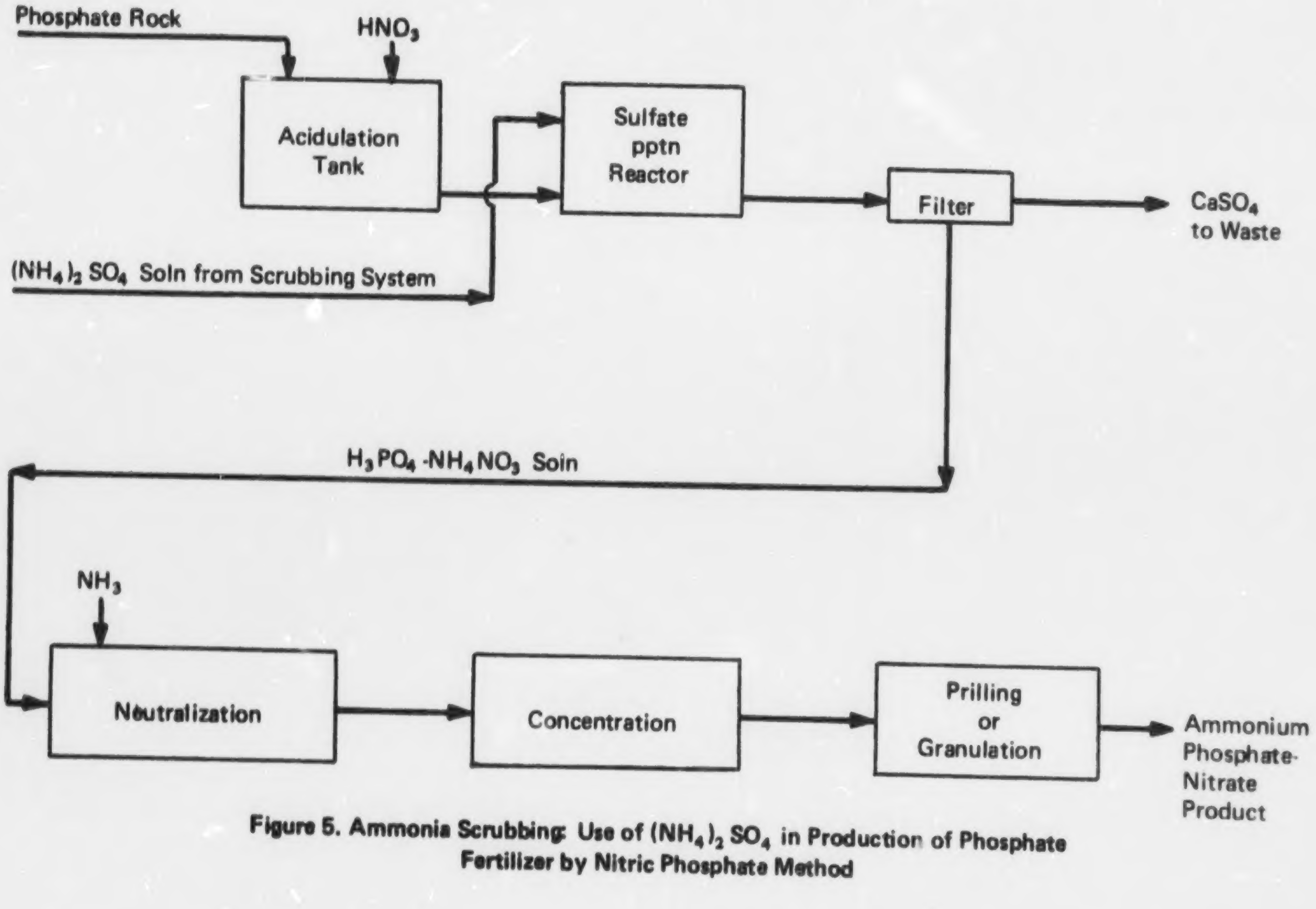

Phosphate Rock
HNO$_3$
Acidulation Tank
Sulfate pptn Reactor
Filter
CaSO$_4$ to Waste
(NH$_4$)$_2$ SO$_4$ Soln from Scrubbing System
H$_3$PO$_4$-NH$_4$NO$_3$ Soln
NH$_3$
Neutralization
Concentration
Prilling or Granulation
Ammonium Phosphate-Nitrate Product

Figure 5. Ammonia Scrubbing: Use of $(NH_4)_2SO_4$ in Production of Phosphate Fertilizer by Nitric Phosphate Method

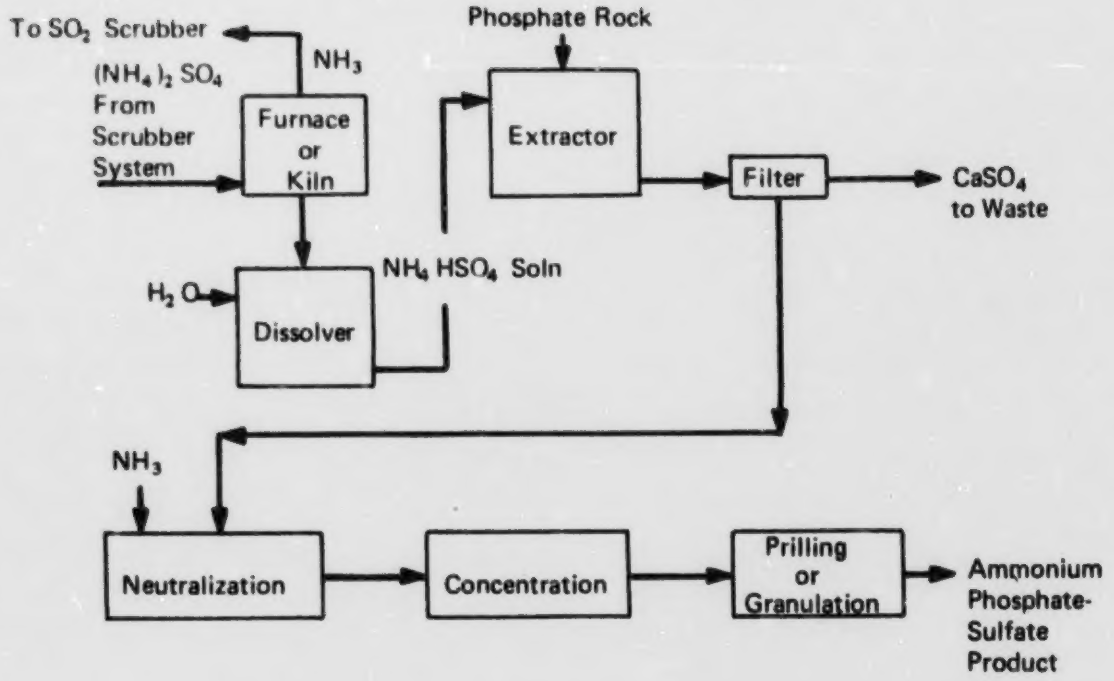

To SO_2 Scrubber
NH_3
$(NH_4)_2SO_4$ From Scrubber System
Furnace or Kiln
Phosphate Rock
Extractor
Filter
$CaSO_4$ to Waste
H_2O
Dissolver
NH_4HSO_4 Soln
NH_3
Neutralization
Concentration
Prilling or Granulation
Ammonium Phosphate-Sulfate Product

Figure 6. Ammonia Scrubbing: Use of $(NH_4)_2SO_4$ in Production of Phosphate Fertilizer by Bisulfate Method

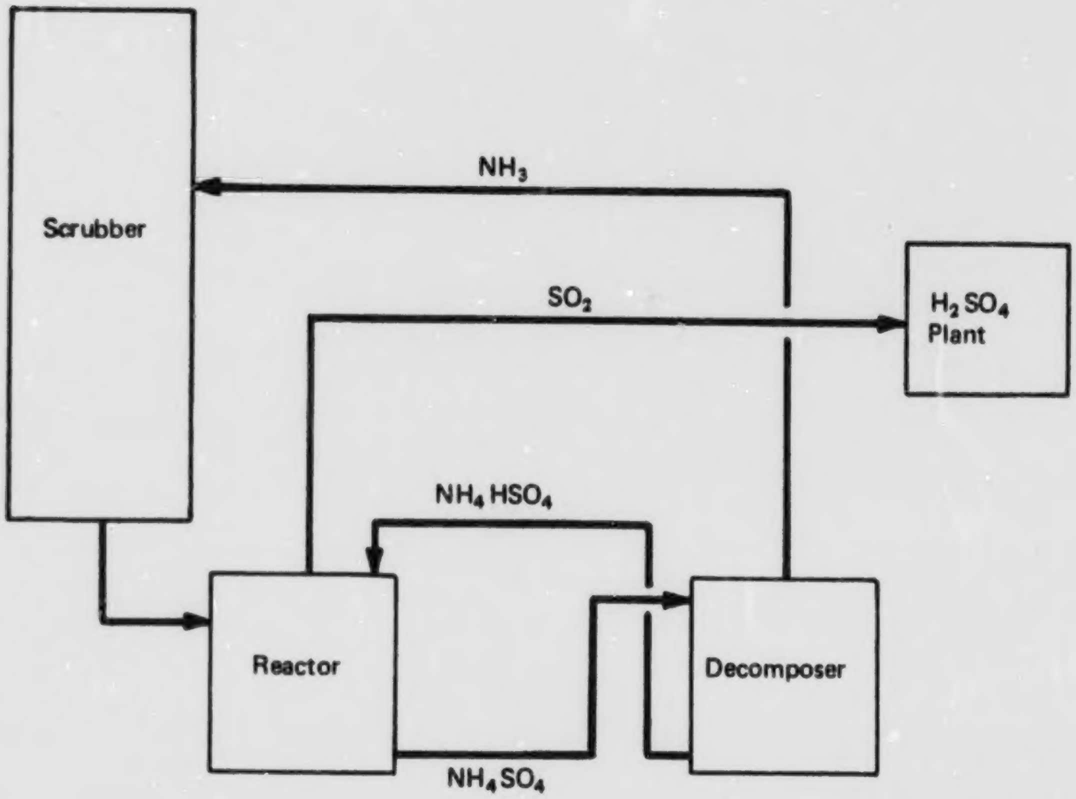

Scrubber
NH_3
SO_2
H_2SO_4 Plant
NH_4HSO_4
Reactor
Decomposer
NH_4SO_4

Figure 7. Ammonia Scrubbing: Acidification of Effluent with NH_4HSO_4

HISTORY AND STATUS

Removal of sulfur oxides from gas streams by reaction with ammonia or absorption in ammoniacal solution has been a subject of research since the beginnings of the chemical industry. In fact, the earliest reference found in the present survey was a patent by Ramsey in 1883 (72). The original objective was not control of sulfur oxide emission from power plants, however, but rather production of ammonium sulfate without going through the sulfuric acid step and, later, removal of sulfur dioxide from the stack gas of sulfuric acid plants and smelters.

Some of the early sulfur oxide scrubbing work beyond the test tube scale was done in Japan, where in 1926 the Japanese Government Chemical Research Institute completed development of an "Oxy-Oxidation" method. After tests with a 3- to 4-metric tons per day (mt/day) unit in 1931, a 60-mt/day ammonium sulfate plant was built in 1935, followed by a 200-mt/day plant in Manchukuo in 1937. Pyrite was burned to supply the sulfur dioxide, which was absorbed by ammonium sulfite solution (4 molar). The solution was then neutralized with ammonia and oxidized to ammonium sulfate by oxygen or air, at 2-3 and 8-9 atmospheres, respectively (43).

Early work on applying ammonia scrubbing to recovery of sulfur oxides from waste gases was carried out by the American Smelting and Refining Company and by the Consolidated Mining and Smelting Company (now Cominco, Ltd.), the latter beginning in about 1932. Operation of zinc and lead smelters at Trail, B. C., by Cominco gave rise to a pollution problem, part of which was solved by installing sulfuric acid plants to recover sulfur dioxide from the zinc smelter waste gas. The gas from the lead smelter was too low in sulfur dioxide content for acid manufacture, however, so ammonia scrubbing was developed as an alternate. This work culminated in installation of a commercial unit in 1936 (60).

The gas from the lead plant contained only about 0.3% sulfur dioxide; however, modifications to the sintering machines and the gas-treating system raised the concentration to over 1%. The ammonium sulfite-bisulfite solution from the scrubbing step was acidified by treatment with sulfuric acid to drive off sulfur dioxide from the bisulfite. About 44% of the sulfur was evolved as sulfur dioxide and the remainder was produced as ammonium sulfate, for which Cominco had a use in fertilizer plants operated in conjunction with the smelter.

The evolved sulfur dioxide was initially converted to elemental sulfur by a Cominco-developed process in which the gas was passed through a bed of incandescent coke. Production was about 150 tons/day of sulfur in the three reduction units constructed (57). In 1943 the increasing need for sulfuric acid in the Cominco operations resulted in closing down the reduction units and using the sulfur dioxide to make acid.

In 1945 Cominco installed a unit to remove sulfur oxides from sulfuric acid tail gas by ammonia scrubbing (27). This process was later installed on acid plants by the Olin Mathieson Company in the United States.

In other work (57), Cominco developed a thermal stripping process, called the "exorption" method. A commercial plant containing six exorption units was built and operated for some time. Pilot plant work was done also on an autoclave method, in which the scrubber effluent was heated under pressure to disproportionate the ammonium bisulfite to ammonium sulfate and elemental sulfur (similar to the older Katasulf method).

During much of the period in which the Cominco developments were taking place, work was under way also by Johnstone and coworkers at the University of Illinois. Five major papers were published in the period 1935-1952 on the basic chemistry of sulfur oxide absorption in ammoniacal solutions and on desorption from the scrubber effluent (45, 46, 47, 48, 50). Careful measurements of vapor pressures in the system were made and the merits of thermal stripping, acidification, and oxidation compared as methods for regenerating the solution. Johnstone concluded that stripping was the most expensive of the three.

Also in the mid-1930's the U. S. Bureau of Mines did fundamental work on various aspects of ammonia scrubbing as applied to cleaning smelter gas, including measurement of vapor pressures, addition of gaseous ammonia to the stack gas, and oxidation of ammonium sulfite solution (87). American Smelting and Refining did pilot work on the Guggenheim process (87), similar to the Cominco exorption method. The evolved sulfur dioxide was reduced by reaction with coke.

The autoclave process was applied to the cleaning of power plant stack gas in the 1940's by Simon-Carves, Ltd., an English engineering firm (56). Various pilot and prototype units were built and tested, for gas flows of 2,000, 56,000, and 60,000 cubic feet per minute (cfm). The process was considered promising by the developers at the time (28), and the possibility of profitable operation was advanced. However, no further effort toward commercial development has been reported.

In the United States, TVA did pilot plant work, beginning in 1953, on adapting ammonia scrubbing to use in power plants burning high-sulfur coal (41). It was demonstrated that the scrubbing step is operable over a fairly wide range of conditions with acceptable efficiency, and that fairly short scrubbing towers should be adequate.

Further work in the 1950's included use of the acidification method on smelter gas by the National

Smelting Company in England (93). There was further use of ammonia scrubbing in Japan also; Nakagawa (67) reports plant installations by Chyu Yu Chemical, Nippon Suiso, Hito Chemical (Yahe plant), Tohoku Fertilizer (Akida plant), and Syowa Electric (Kawasaki plant). Plants were reported also for German Tiran (Traboncol, Kerala State, India) and Degussa (Frankfurt, Germany). The type of plant producing the sulfur dioxide was not given; presumably most of them were sulfuric acid plants. Nakagawa reported in 1968 that none of the Japanese plants are still in operation.

A Cominco-type unit was installed in the 1950's to clean sulfuric acid at Fertilizers and Chemicals, Travancore (Alwaye, Kerala, India; this may be the same as the plant in India referred to by Nakagawa). The evolved sulfur dioxide is dried and either liquefied for sale or returned to the acid plant feed.

There has been a rapid expansion of work on applying ammonia scrubbing to the power plant problem in the 1960-1970 decade. One of the major efforts has been the work of Chertkov and coworkers at the NIIOGAZ (Scientific Research Institute for Industrial and Sanitary Purification of Gases) in Russia, beginning in the late 1950's and apparently still continuing (last paper in 1967). Over 40 papers have been published by Chertkov on sulfur oxide recovery, most of them involving ammonia scrubbing. All phases of the subject have been covered: basic chemical data, mass transfer in scrubbers, the autoclave process, regeneration by stripping, solution oxidation, and solution decomposition. Much of the work was on a pilot plant scale.

Chertkov's investigations apparently have led to installation of a commercial unit. It was reported in 1967 (36) that a unit was being operated at the Voskresensky Chemical Combine in which the stripping method was used. Apparently no information has been made available on the size and operating details.

In an earlier paper (22), Chertkov stated that an ammonia scrubbing unit had been "operated for many years" on a boiler of the Mosenergo TETS- 12 power plant (Moscow region). No details are given other than that the product is liquid sulfur dioxide, indicating that stripping is involved. The production reported, 5,000-7,000 tons/year (tons/yr), indicates a very small unit.

Work on ammonia scrubbing has also been continued in Japan. Nakagawa (68) reported units at Nitto Chemical Company (Hachinohe plant, presumably sulfuric acid) and Showa Denko Company (Kawasaki plant). The latter is a 25-mw test unit operating on stack gas from an oil-burning boiler supplying process steam for other Showa Denko operations. The scrubber effluent is oxidized to produce ammonium sulfate.

In France, Electricite de France built a 25-mw test unit for ammonia scrubbing in 1967 (64). In cooperation with Weirtam (an engineering firm) and Ugine Kuhlmann (a chemical process engineering-design firm). The first unit did not involve sulfur dioxide recovery; the scrubber solution was treated with lime to produce calcium sulfate for disposal and ammonia for recycle. In a second development phase, a stripping process was worked out that is claimed to have a very low steam requirement (39). The test unit has been revamped for the new process and was started up early in 1969; successful operation has been reported but no data have been made available.

In Czechoslovakia, the Fuel Research Institute (Prague) has done pilot plant studies [20,000 normal cubic meters per hour (Nm^3/hr) or about 5 mw] on ammonia scrubbing of power plant gas (77). Most of the work has been on the acidification method, with the gas cooled to a relatively low degree to improve process operation. A full-scale unit (110-mw) has been planned for the Tusimice I power station, scheduled for startup in 1971, and a larger unit (800-mw, Tusimice II) is being considered for 1973-1974. Two units for scrubbing sulfuric acid tail gas are already in operation, one producing ammonium sulfate and the other ammonium sulfate plus ammonium nitrate.

In 1968, NAPCA and TVA entered into a contract for further development of ammonia scrubbing, with particular reference to scrubbing problems on which insufficient information is available from the literature. A pilot plant is under construction at the TVA Colbert Steam Plant, near Sheffield, Alabama.

This account is by no means a complete survey of ammonia scrubbing history. Numerous organizations have worked on the process over the past 50 years and taken patents on their developments; complete coverage of the patent literature has not been attempted and there may also be developments in sulfuric acid tail gas cleaning and in ammonium sulfate production from rich gases that have not been identified.

Application of the ammonia scrubbing process is relatively well advanced as compared with other processes, with large power plant test units in Czechoslovakia, Russia, France, and Japan; commercial units on sulfuric acid and smelter tail gas in Czechoslovakia, Canada, United States, Japan, and India; and pilot plant work in several countries. The method continues to offer the promise of high solution capacity, low absorbent cost, and salability of the sulfate unavoidably produced. If the scrubber problems can be solved and a more economical regeneration method developed, the process may compare well with other methods for sulfur oxide recovery.

CHEMISTRY AND KINETICS OF SULFUR OXIDE ABSORPTION

The chemical equilibria and kinetics involved in absorption of sulfur dioxide by ammoniacal solutions have been studied extensively. In addition to the major work of Johnstone on equilibria, which was aimed primarily at the power plant problem, the system NH_3-SO_2-H_2O has been studied in a general way and also in connection with the ammonium sulfite process for wood pulping.

Equilibria Involved

Scott and McCarthy (76) studied the system both experimentally and theoretically with the objective of determining the species present. Only H^+, OH^-, HSO_3^-, SO_3^{2-}, NH_4^+, and solvated forms of SO_2 and NH_3 were found to exist in the solutions in significant amounts. In the pH range 4.2-7.0, only HSO_3^-, SO_3^{2-}, and NH_4^+ were present. An equation was developed for calculating species concentrations as a function of pH.

$$\frac{[HSO_3^-]}{[SO_3^{2-}]} \simeq 1.59 \times 10^7\ [H^+] \qquad (14)$$

The concentration of NH_4^+, of course, is equal to $[HSO_3^-] + 2\,[SO_3^{2-}]$.

Calculations have been made by Egan (30) to determine whether the thermodynamics favor reaction of ammonia with sulfur dioxide rather than carbon dioxide, since the stack gas contains far more carbon dioxide than sulfur dioxide. The reactions considered were

$$2NH_3(g) + H_2O(liq) + SO_2(g) = (NH_4)_2SO_3(c) \qquad (15)$$
$$2NH_3(g) + H_2O\ (liq) + CO_2(g) = (NH_4)_2CO_3(c) \qquad (16)$$
$$2NH_3(g) + CO_2(g) = NH_4COONH_2(c) \qquad (17)$$
$$NH_3(g) + H_2O(liq) + CO_2(g) = NH_4HCO_3(c) \qquad (18)$$
$$(NH_4)_2CO_3(c) + SO_2(g) \quad (NH\ \ )\ CO\ \ (c) + SO\ \ (g)$$
$$= (NH_4)_2SO_3(c) + CO_2(g) \qquad (19)$$
$$NH_4COONH_2(c) + SO_2(g) + H_2O(liq)$$
$$= (NH_4)_2SO_3(c) + CO_2(g) \qquad (20)$$
$$2(NH_4)_2SO_3(c) + O_2(g) = 2(NH_4)_2SO_4(c) \qquad (21)$$
$$2SO_2(g) + O_2(g) = 2SO_3(g) \qquad (22)$$

The free energies of reaction are shown in figure 8 and the equilibrium constants are listed in table 1. Figure 8 shows that reactions 15 through 20 are favored by low temperature, and that sulfur dioxide will displace carbon dioxide in the solid products.

For equations 21 and 22, the thermodynamics favor both oxidations at the lower temperatures (the free energies are beyond the scale of figure 8). It was necessary to estimate the entropy of solid ammonium sulfite (by an established method), so that the thermodynamics for reactions involving this salt are somewhat uncertain.

Table 1. Reactions of NH_3 with SO_2 and CO_2

	Equibilibrium constant, log K_p, for indicated equation No.							
T, °K	2	3	4	5	6	7	8	9
300	10.37	3.70	3.46	3.00	6.67	6.96	94.16	24.42
350	5.10	-0.53	-0.50	-0.08	5.63	5.65	79.55	19.52
400	1.15	-3.70	-3.48	-2.38	4.85	4.66	68.58	15.85
450	-1.92	-6.17	-5.79	-4.18	4.25	3.90	60.06	13.00
500	-4.38	-8.15	-7.64	-5.62	3.76	3.29	53.24	10.71
550	-6.40	-9.76	-9.15	-6.79	3.37	2.79	47.66	8.85
600	-8.07	-11.11	-10.41	-7.77	3.04	2.37	43.00	7.30

Equation No.	Free energy equation
2	$\Delta F = -50{,}640 + 121.34T$
3	$\Delta F = -40{,}660 + 118.60T$
4	$\Delta F = -38{,}079 + 111.10T$
5	$\Delta F = -29{,}593 + 84.89T$
6	$\Delta F = -9{,}980 + 2.74T$
7	$\Delta F = -12{,}603 + 10.16T$
8	$\Delta F = -140{,}460 + 37.30T$
9	$\Delta F = -47{,}006 + 44.75T$

The question of whether carbon dioxide will displace sulfur dioxide from solution has been considered by Aerojet-General Corporation (1). The basic equation is

$$CO_2 + HSO_3^- = SO_2 + HCO_3^- \qquad (23)$$

The free energy change of this reaction was found to be plus 8.2 kilocalories (kcal) at 25° C and the entropy change plus 5.04 entropy units. The free energy change at 50° C was calculated to be over 8.0 kcal and the equilibrium constant, K, was 4×10^{-6}. For:

$$\frac{(HCO_3^-)}{(HSO_3^-)} = K\,P_{CO_2}/P_{SO_2} \qquad (24)$$

and assuming P_{CO_2} = 112 millimeters (mm) and P_{SO_2} = 2.28 mm in the gas, the bicarbonate to bisulfite ratio at the bottom of the scrubber was calculated to be 2×10^{-4}, indicating that practically no bicarbonate would be present.

Vapor Pressure

The vapor pressure of sulfur dioxide over ammonium sulfite-bisulfite solutions is a highly important consideration in ammonia scrubbing. The basic data on vapor pressure were determined by Johnstone (44), who made determinations at several concentrations and over the pH range of 4.71-5.96. The results could be expressed by equations:

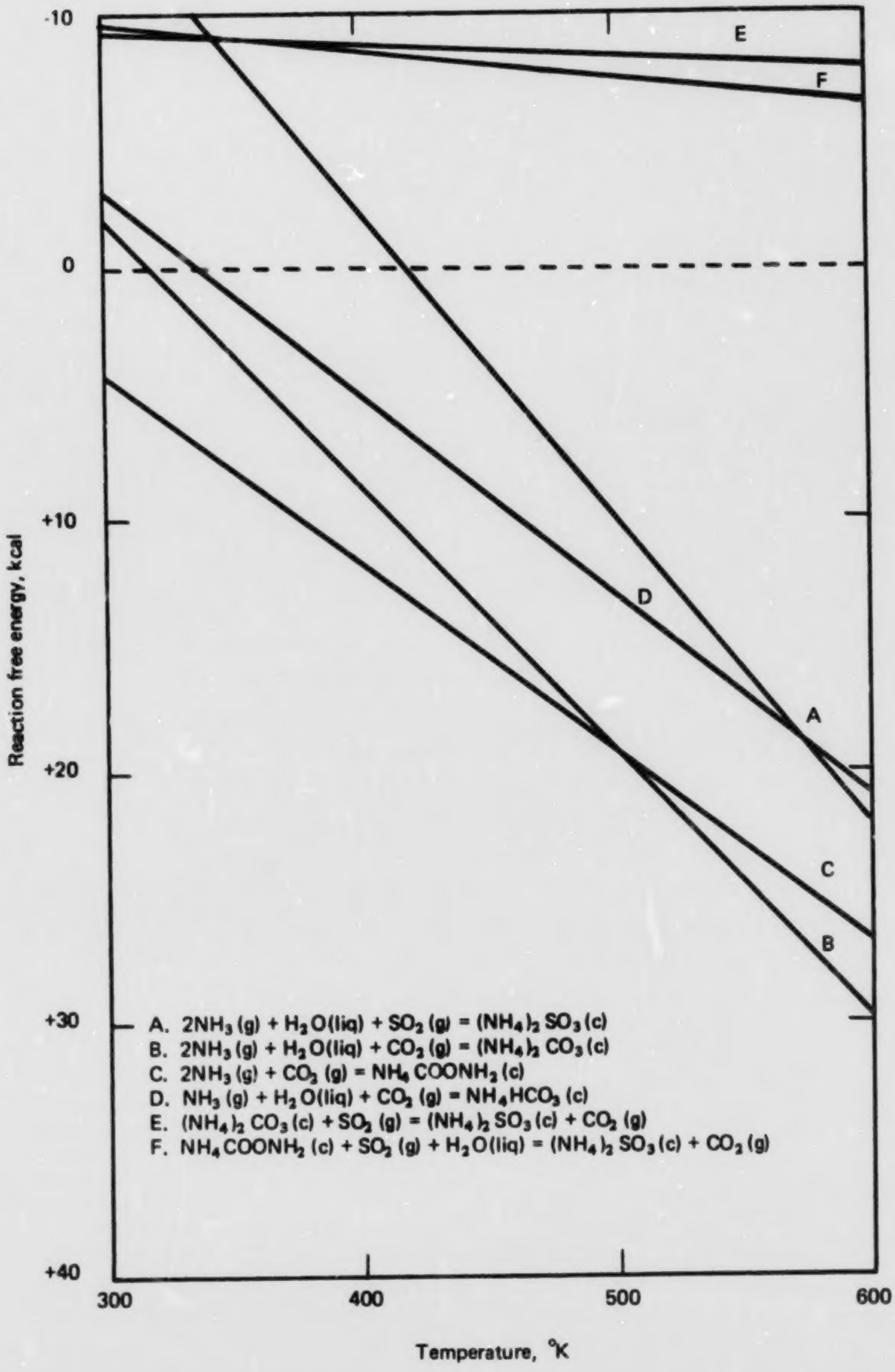


Figure 8. Reactions of NH_3 with SO_2 and CO_2

$$P_{SO_2} = M\frac{(2S - C)^2}{C - S} \qquad (25)$$

$$P_{NH_3} = N\frac{C(C - S)}{2S - C} \qquad (26)$$

where C is the concentration of ammonia in moles/100 moles of water and S is the concentration of sulfur dioxide. The values used by Johnstone for the constants are:

$$\log M = 5.865 - \frac{2369}{T} \qquad (27)$$

$$\log N = 13.680 - \frac{4987}{T} \qquad (28)$$

M and N vary with concentration but the variation is not enough to introduce any great error over the practical range of concentration. The approximate values at 125°F, the probable practical level of scrubbing temperature, are M = 0.0380 and N = 0.0233.

For the practical scrubbing system, in which sulfate is present, the partial pressure equations become:

$$P_{SO_2} = M\frac{(2S - C + 2A)^2}{C - S - 2A} \qquad (29)$$

$$P_{NH_3} = N\frac{C(C - S - 2A)}{2S - C + 2A} \qquad (30)$$

where A is the sulfate concentration in moles/100 moles of water. Thus as far as the partial pressure of sulfur dioxide is concerned, oxidation merely reduces the effective concentration of ammonia and therefore increases the sulfur dioxide pressure.

Chertkov (23) also determined vapor pressure over solutions containing sulfate. The following equation was derived from the data:

$$P_{SO_2}\ (\text{true}) = P_{SO_2}\ (\text{calcd})\,\frac{C + A}{C} \qquad (31)$$

where P_{SO_2} (calcd) is the value obtained by the Johnstone equations without any allowance for sulfate. The effect of sulfate content in Chertkov's tests is shown in figure 9.

The partial pressure of water can be represented adequately by the Raoult relationship:

$$P_{H_2O} = P_w \left[\frac{100}{100 + C + S}\right] \qquad (32)$$

where Pw = vapor pressure of pure water at the temperature involved.

The effect of temperature on vapor pressure was represented in Johnstone's work by the Young equation:

$$\log P = a + {}^{b}/T \qquad (33)$$

The constants a and b are the same as in equations 27 and 28 where the values over the experimental range have been averaged. The molar heat of absorption can be approximated by multiplying constant b by 4.58. For sulfur dioxide, the values ranged from minus 9,500-11,500 cal/mole, and for ammonia minus 19,400 to minus 22,900/mole.

The equations of Johnstone have been programmed in the present study and the vapor pressures calculated over a range of temperature and S/C (table 2). Curves for the pressures at key temperatures are given in figure 10.

The vapor pressure of ammonia and sulfur dioxide over the solid salts is also of interest, as some have proposed ammonia injection into the gas ahead of the scrubber. Both the Showa Denko and Electricite de France processes involve addition of ammonia in this way, and Electricite de France claims that mass transfer into the scrubber solution is improved by first forming solid sulfite-bisulfite (or pyrosulfite) in the gas stream and then using the scrubber as a "dust collector" to recover it.

St. Clair (U. S. Bureau of Mines) (87) determined such vapor pressures as part of a study on recovery of sulfur dioxide from smelter gases. In the same study, Marks and Ambrose attempted recovery in a solid form by adding ammonia and water vapor to the gas and collecting the resulting solid.

St. Clair's data for the system $(NH_4)_2S_2O_5$-$(NH_4)_2SO_3$-SO_2 are shown in figure 11. (At the temperatures he used, pyrosulfite is obtained rather than bisulfite.) Earhart (NAPCA) (29) has reviewed and analyzed the data of St. Clair and of Ambrose and Marks. He concluded that addition of ammonia to power plant stack gas cooled to 125° F by direct contact with water should give solid $(NH_4)_2SO_3 \cdot H_2O$ as the sole product and that only about 63% of the sulfur dioxide should react.

pH

Johnstone developed an equation for the pH of ammonium sulfite-bisulfite solutions:

$$\text{pH} = -4.62\,(S/C) + 9.2 \qquad (34)$$

The equation cannot be used all the way to the bisulfite ratio (S/C = 1.0). Measured pH for bisulfite is approximately 4.1, which could not, of course, be reached in an actual scrubbing system. The pH at a bisulfite to sulfite mole ratio of 2:1 (S/C = 0.83), which should be attainable, is about 5.7–perhaps high enough for adequate corrosion resistance. Johnstone found this to be true in the pilot plant his staff operated for a long period; there was little corrosion of the mild steel used. (Others, however, have encountered corrosion.)

For a given vapor pressure of sulfur dioxide, increase in solution concentration increased the pH (49).

Table 2. Vapor Pressures in the System NH_3-SO_2-H_2O, mm Hg

		Percent			Temperature, °F																				
					85			105			125			145			165			185			205		
C[a]	S[b]	NH_3	SO_2	pH	P_{SO_2}	P_{NH_3}	P_{H_2O}	P_{SO_2}	P_{NH_3}	P_{H_2O}	P_{SO_2}	P_{NH_3}	P_{H_2O}	P_{SO_2}	P_{NH_3}	P_{H_2O}	P_{SO_2}	P_{NH_3}	P_{H_2O}	P_{SO_2}	P_{NH_3}	P_{H_2O}	P_{SO_2}	P_{NH_3}	P_{H_2O}
2	1.9	1.74	6.22	4.8	0.38	0.00	35	0.67	0.00	61	1.21	0.00	104	2.11	0.01	172	3.54	0.02	273	5.77	0.06	423	8.17	0.17	637
	1.8	1.74	5.91	5.0	0.14	0.00	35	0.26	0.00	61	0.48	0.01	105	0.83	0.02	172	1.40	0.05	274	2.28	0.14	423	3.60	0.37	638
	1.7	1.75	5.60	5.3	0.07	0.00	35	0.13	0.00	61	0.24	0.01	105	0.42	0.03	172	0.71	0.09	274	1.16	0.24	424	1.84	0.64	639
	1.6	1.76	5.29	5.5	0.04	0.00	35	0.07	0.00	62	0.13	0.01	105	0.23	0.05	172	0.39	0.14	274	0.64	0.38	424	1.01	1.00	639
	1.5	1.76	4.97	5.7	0.02	0.00	35	0.04	0.01	62	0.07	0.02	105	0.13	0.07	172	0.22	0.20	274	0.36	0.57	425	0.56	1.50	640
	1.4	1.77	4.66	6.0	0.01	0.00	35	0.02	0.01	62	0.04	0.03	105	0.07	0.10	173	0.12	0.31	275	0.19	0.86	425	0.30	2.24	640
	1.3	1.77	4.34	6.2	0.01	0.00	35	0.01	0.01	62	0.02	0.05	105	0.03	0.16	173	0.06	0.48	275	0.09	1.33	425	0.14	3.40	641
	1.2	1.78	4.02	6.4	0.00	0.01	35	0.01	0.02	62	0.01	0.09	105	0.01	0.27	173	0.02	0.82	275	0.04	2.20	426	0.06	5.90	642
	1.1	1.79	3.70	6.7	0.00	0.01	35	0.00	0.05	62	0.00	0.19	105	0.00	0.62	173	0.00	1.84	276	0.01	5.13	426	0.01	13.5	642
4	3.8	3.22	11.5	4.8	0.70	0.00	33	1.31	0.00	59	2.47	0.00	101	4.21	0.02	165	7.09	0.05	264	11.5	0.13	408	18.2	0.33	614
	3.6	3.24	11.0	5.0	0.28	0.00	33	0.53	0.00	59	0.96	0.01	101	1.66	0.03	166	2.80	0.12	264	4.56	0.28	408	7.21	0.79	615
	3.4	3.26	10.4	5.3	0.14	0.00	34	0.27	0.01	59	0.48	0.02	101	0.85	0.06	166	1.43	0.18	264	2.33	0.48	409	3.68	1.28	617
	3.2	3.28	9.88	5.5	0.08	0.00	34	0.15	0.01	60	0.27	0.03	101	0.47	0.09	166	0.79	0.27	265	1.28	0.78	410	2.03	2.00	618
	3.0	3.30	9.32	5.7	0.04	0.00	34	0.08	0.01	60	0.15	0.04	101	0.26	0.14	167	0.44	0.41	265	0.71	1.16	411	1.13	2.90	619
	2.8	3.32	8.75	6.0	0.02	0.00	34	0.04	0.02	60	0.08	0.06	102	0.14	0.21	167	0.23	0.61	266	0.38	1.71	411	0.60	4.40	620
	2.6	3.35	8.18	6.2	0.01	0.01	34	0.02	0.03	60	0.04	0.10	102	0.07	0.32	167	0.11	0.95	266	0.18	2.66	412	0.29	6.90	621
	2.4	3.37	7.60	6.4	0.00	0.01	34	0.01	0.05	60	0.01	0.17	102	0.03	0.55	168	0.05	1.63	267	0.07	4.50	413	0.11	12.0	622
	2.2	3.39	7.01	6.7	0.00	0.03	34	0.00	0.11	60	0.00	0.36	102	0.01	1.23	168	0.01	3.60	267	0.02	10.3	414	0.03	26.9	624
6	5.7	4.50	16.1	4.8	1.06	0.00	32	2.00	0.00	57	3.63	0.01	97	6.32	0.02	160	10.6	0.07	254	17.3	0.19	393	27.4	0.50	593
	5.4	4.54	15.4	5.0	0.42	0.00	32	0.79	0.00	57	1.43	0.02	97	2.50	0.05	160	4.20	0.15	255	6.84	0.43	394	10.8	1.12	594
	5.1	4.58	14.6	5.3	0.21	0.00	32	0.40	0.01	57	0.73	0.03	98	1.27	0.09	161	2.14	0.26	256	3.49	0.73	396	5.52	1.92	596
	4.8	4.62	13.9	5.5	0.12	0.00	32	0.22	0.01	58	0.40	0.04	98	0.70	0.14	161	1.19	0.41	256	1.92	1.14	397	3.04	2.90	598
	4.5	4.66	13.2	5.7	0.07	0.00	33	0.12	0.02	58	0.22	0.06	98	0.39	0.21	161	0.66	0.61	257	1.07	1.71	398	1.69	4.40	599
	4.2	4.70	12.4	6.0	0.03	0.01	33	0.07	0.03	58	0.12	0.10	98	0.21	0.31	162	0.35	0.92	258	0.57	2.57	399	0.90	6.73	601
	3.9	4.74	11.6	6.2	0.02	0.01	33	0.04	0.04	58	0.06	0.15	99	0.10	0.48	162	0.17	1.43	259	0.27	3.99	400	0.43	10.5	603
	3.6	4.78	10.8	6.4	0.01	0.02	33	0.01	0.07	58	0.02	0.25	99	0.04	0.82	163	0.07	2.45	259	0.11	6.44	401	0.17	18.0	604
	3.3	4.83	10.0	6.7	0.00	0.04	33	0.00	0.16	58	0.00	0.47	99	0.01	1.85	163	0.01	5.92	260	0.03	15.4	402	0.04	40.4	606
8	7.6	5.62	20.1	4.8	1.41	0.00	31	2.67	0.00	55	4.84	0.01	94	8.43	0.03	154	14.2	0.09	246	23.1	0.29	380	36.5	0.67	573
	7.2	5.68	19.2	5.0	0.54	0.00	31	1.05	0.01	55	1.91	0.02	94	3.33	0.07	155	5.60	0.20	247	9.12	0.57	381	14.4	1.50	575
	6.8	5.74	18.4	5.3	0.28	0.00	31	0.54	0.01	55	0.98	0.04	95	1.70	0.12	155	2.86	0.35	247	4.65	0.98	383	7.36	2.57	577
	6.4	5.80	17.5	5.5	0.16	0.00	31	0.30	0.02	56	0.54	0.06	95	0.94	0.18	156	1.57	0.54	248	2.56	1.52	384	4.06	3.99	579
	6.0	5.87	16.6	5.7	0.09	0.01	32	0.16	0.02	56	0.30	0.08	95	0.52	0.27	156	0.87	0.82	249	1.42	2.28	385	2.25	5.99	581
	5.6	5.93	15.6	6.0	0.05	0.01	32	0.09	0.04	56	0.16	0.13	96	0.28	0.41	157	0.47	1.23	250	0.76	3.42	387	1.21	8.90	583
	5.2	6.00	14.7	6.2	0.02	0.01	32	0.04	0.06	56	0.08	0.20	96	0.13	0.64	158	0.22	1.91	251	0.37	5.32	388	0.58	14.0	585
	4.8	6.07	13.7	6.4	0.01	0.03	32	0.02	0.10	57	0.03	0.34	96	0.05	1.09	158	0.09	3.27	252	0.14	9.12	390	0.23	23.0	587
	4.4	6.14	12.7	6.7	0.00	0.06	32	0.00	0.22	57	0.01	0.76	97	0.01	2.40	159	0.02	7.35	253	0.03	20.5	391	0.05	53.0	589
10	9.5	6.60	23.6	4.8	1.74	0.00	30	3.33	0.00	53	6.14	0.01	91	10.5	0.04	149	17.7	0.11	238	28.0	0.32	368	45.6	0.83	554
	9.0	6.69	22.6	5.0	0.70	0.00	30	1.32	0.01	54	2.39	0.03	91	4.14	0.08	150	7.00	0.26	239	11.4	0.71	369	18.0	1.87	556
	8.5	6.77	21.6	5.3	0.34	0.00	30	0.67	0.01	54	1.22	0.05	92	2.12	0.15	151	3.57	0.44	240	5.82	1.22	371	9.20	3.21	559
	8.0	6.86	20.6	5.5	0.20	0.01	31	0.37	0.02	54	0.67	0.07	92	1.17	0.23	151	1.97	0.68	241	3.21	1.90	372	5.07	4.99	561
	7.5	6.94	19.6	5.7	0.11	0.01	31	0.21	0.03	54	0.37	0.11	92	0.65	0.34	152	1.09	1.02	242	1.78	2.85	374	2.82	7.48	564
	7.0	7.04	18.5	6.0	0.06	0.01	31	0.11	0.05	54	0.20	0.16	93	0.35	0.51	152	0.58	1.53	243	0.95	4.28	376	1.50	11.2	566
	6.5	7.13	17.4	6.2	0.03	0.02	31	0.05	0.07	55	0.10	0.25	93	0.17	0.80	153	0.28	2.38	244	0.46	6.65	377	0.72	17.5	568
	6.0	7.23	16.3	6.4	0.01	0.03	31	0.02	0.12	55	0.04	0.42	94	0.07	1.37	154	0.11	4.09	245	0.18	11.4	379	0.28	29.0	571
	5.5	7.33	15.2	6.7	0.00	0.07	31	0.00	0.27	55	0.01	0.90	94	0.01	3.08	154	0.02	9.19	246	0.04	25.7	380	0.06	67.3	573
12	11.4	7.47	26.7	4.8	2.11	0.00	29	4.00	0.00	52	7.28	0.01	88	12.6	0.05	145	21.3	0.14	230	34.6	0.38	356	54.7	1.00	537
	10.8	7.58	25.6	5.0	0.93	0.00	29	1.66	0.01	52	2.87	0.03	88	4.99	0.10	145	8.40	0.31	231	13.7	0.86	358	21.6	2.24	539
	10.2	7.69	24.6	5.3	0.45	0.00	29	0.81	0.02	52	1.44	0.05	89	2.55	0.18	146	4.29	0.53	232	6.98	1.47	360	11.0	3.85	542
	9.6	7.80	23.5	5.5	0.24	0.01	30	0.44	0.02	52	0.81	0.08	89	1.40	0.27	147	2.36	0.82	234	3.85	2.28	361	6.09	5.99	545
	9.0	7.91	22.3	5.7	0.13	0.01	30	0.25	0.04	53	0.45	0.13	90	0.78	0.41	147	1.31	1.23	235	2.14	3.42	363	3.38	8.99	547
	8.4	8.03	21.2	6.0	0.07	0.01	30	0.13	0.05	53	0.24	0.19	90	0.42	0.62	148	0.70	1.84	236	1.14	5.13	365	1.80	13.5	550
	7.8	8.16	19.9	6.2	0.03	0.02	30	0.06	0.09	53	0.12	0.30	91	0.20	0.96	149	0.34	2.86	237	0.55	7.98	367	0.87	20.9	553
	7.2	8.28	18.7	6.4	0.01	0.04	30	0.02	0.15	53	0.04	0.51	91	0.08	1.66	150	0.13	4.90	238	0.21	13.7	369	0.34	35.9	556
	6.6	8.42	17.4	6.7	0.00	0.09	30	0.01	0.33	54	0.01	1.15	92	0.02	3.69	150	0.03	11.0	240	0.05	30.8	371	0.08	80.8	558
14	13.3	8.24	29.5	4.8	2.47	0.00	28	4.67	0.00	50	8.46	0.02	85	14.7	0.05	140	24.8	0.16	223	40.4	0.44	345	63.9	1.16	520
	12.6	8.37	28.4	5.0	0.97	0.00	28	1.84	0.01	50	3.34	0.04	86	5.83	0.12	141	9.80	0.36	224	16.0	1.00	347	25.2	2.62	523
	11.9	8.51	27.2	5.3	0.50	0.00	29	0.94	0.02	51	1.71	0.06	86	2.97	0.21	142	5.00	0.61	226	8.14	1.71	349	12.9	4.49	526
	11.2	8.65	26.0	5.5	0.27	0.01	29	0.52	0.03	51	0.94	0.10	87	1.64	0.32	142	2.76	0.95	227	4.49	2.66	351	7.10	6.98	529
	10.5	8.79	24.8	5.7	0.15	0.01	29	0.29	0.04	51	0.52	0.15	87	0.91	0.48	143	1.53	1.43	228	2.49	3.99	353	3.94	10.5	532
	9.8	8.94	23.5	6.0	0.08	0.02	29	0.15	0.06	51	0.28	0.22	88	0.49	0.72	144	0.82	2.15	229	1.33	5.99	355	2.10	15.7	535
	9.1	9.09	22.2	6.2	0.04	0.03	29	0.07	0.10	52	0.13	0.35	88	0.23	1.12	145	0.39	3.34	231	0.64	9.31	357	1.01	24.4	538
	8.4	9.25	20.9	6.4	0.02	0.06	29	0.03	0.17	52	0.05	0.59	89	0.09	1.91	146	0.15	5.72	232	0.25	16.0	359	0.39	41.9	541
	7.7	9.41	19.5	6.7	0.00	0.13	30	0.01	0.38	52	0.01	1.34	89	0.02	4.31	147	0.03	12.9	233	0.06	35.9	361	0.09	94.3	544
16	15.2	8.94	31.9	4.8	2.87	0.00	27	5.34	0.01	49	9.67	0.02	83	16.8	0.06	136	28.3	0.18	217	46.2	0.51	335	73.0	1.33	505
	14.4	9.09	30.8	5.0	1.11	0.00	28	2.11	0.01	49	3.87	0.04	83	6.66	0.14	137	11.2	0.41	218	18.2	1.14	337	28.8	2.90	508
	13.6	9.25	29.6	5.3	0.57	0.01	28	1.09	0.02	49	1.95	0.07	84	3.40	0.23	138	5.72	0.70	219	9.31	1.96	339	14.7	5.13	511
	12.8	9.42	28.3	5.5	0.31	0.01	28	0.59	0.03	49	1.07	0.11	84	1.87	0.36	139	3.15	1.09	221	5.13	3.04	341	8.11	7.98	514
	12.0	9.59	27.0	5.7	0.17	0.01	28	0.33	0.05	50	0.60	0.17	85	1.04	0.55	139	1.75	1.63	222	2.85	4.56	343	4.51	12.0	517
	11.2	9.76	25.7	6.0	0.09	0.02	28	0.18	0.07	50	0.32	0.25	85	0.55	0.82	140	0.93	2.45	223	1.52	6.84	345	2.40	18.0	521
	10.4	9.94	24.3	6.2	0.04	0.03	28	0.08	0.11	50	0.15	0.40	86	0.27	1.28	141	0.45	3.81	225	0.73	10.6	348	1.16	27.9	524
	9.6	10.1	22.9	6.4	0.02	0.05	29	0.03	0.19	51	0.06	0.68	86	0.10	2.19	142	0.17	6.56	226	0.28	18.2	350	0.45	47.9	527
	8.8	10.3	21.4	6.7	0.00	0.11	29	0.01	0.44	51	0.01	1.53	87	0.02	4.92	143	0.04	14.7	228	0.06	41.1	352	0.10	107.7	531
18	17.1	9.57	34.2	4.8	3.17	0.00	27	6.00	0.01	47	10.9	0.02	80	19.0	0.07	132	31.9	0.20	210	51.9	0.57	325	82.1	1.50	490
	16.2	9.74	33.0	5.0	1.25	0.00	27	2.37	0.01	47	4.30	0.05	81	7.49	0.15	133	12.6	0.46	212	20.5	1.28	327	32.4	3.37	493
	15.3	9.92	31.7	5.3	0.64	0.01	27	1.21	0.02	48	2.19	0.08	81	3.82	0.26	134	6.43	0.79	213	10.5	2.20	330	16.6	5.77	497
	14.4	10.1	30.4	5.5	0.35	0.01	27	0.67	0.04	48	1.21	0.13	82	2.11	0.41	135	3.54	1.23	215	5.77	3.42	332	9.12	8.98	500
	13.5	10.3	29.1	5.7	0.20	0.01	27	0.37	0.05	48	0.67	0.19	83	1.17	0.62	136	1.97	1.84	216	3.21	5.13	334	5.07	13.5	504
	12.6	10.5	27.7	6.0	0.10	0.02	28	0.20	0.08	48	0.36	0.29	83	0.62	0.92	137	1.05	2.76	218	1.71	7.70	336	2.70	20.2	507
	11.7	10.7	26.2	6.2	0.05	0.03	28	0.10	0.13	49	0.17	0.45	84	0.30	1.44	138	0.51	4.29	219	0.82	12.0	339	1.30	31.4	511
	10.8	10.9	24.7	6.4	0.02	0.06	28	0.04	0.22	49	0.07	0.76	84	0.12	2.46	139	0.20	7.35	221	0.32	20.5	341	0.51	53.0	514
	9.9	11.2	23.1	6.7	0.00	0.13	28	0.01	0.48	49	0.01	1.72	85	0.03	5.54	139	0.04	16.5	222	0.07	46.2	344	0.11	121.2	518
20	19.0	10.1	36.2	4.8	3.57	0.00	26	6.67	0.01	46	12.1	0.02	78	21.1	0.08	128	35.4	0.23	204	57.7	0.63	316	91.2	1.66	476
	18.0	10.3	35.0	5.0	1.39	0.00	26	2.64	0.02	46	4.78	0.05	78	8.32	0.17	129	14.0	0.51	206	22.8	1.43	318	36.0	3.74	480
	17.0	10.5	33.7	5.3	0.71	0.01	26	1.34	0.03	47	2.44	0.09	79	4.25	0.29	130	7.15	0.88	207	11.6	2.46	321	18.4	6.41	483
	16.0	10.8	32.4	5.5	0.39	0.01	26	0.74	0.04	47	1.34	0.14	80	2.34	0.46	131	3.94	1.36	209	6.41	3.80	323	10.1	9.98	487
	15.0	11.0	31.0	5.7	0.22	0.02	27	0.41	0.06	47	0.75	0.21	80	1.30	0.68	132	2.19	2.04	210	3.56	5.70	326	5.63	15.0	491
	14.0	11.2	29.5	6.0	0.12	0.02	27	0.22	0.09	48	0.40	0.32	81	0.69	1.03	133	1.17	3.06	212	1.90	8.55	328	3.00	22.4	494
	13.0	11.4	28.0	6.2	0.06	0.04	27	0.11	0.14	48	0.19	0.50	82	0.33	1.60	134	0.56	4.77	214	0.92	13.3	330	1.45	34.9	498
	12.0	11.7	26.4	6.4	0.02	0.06	27	0.04	0.24	48	0.07	0.85	82	0.13	2.74	135	0.22	8.17	215	0.36	22.8	333	0.56	59.9	502
	11.0	12.0	24.8	6.7	0.00	0.14	27	0.01	0.55	49	0.01	1.91	83	0.03	6.16	136	0.05	18.4	217	0.08	51.3	335	0.13	134.7	505
22	20.9	10.7	38.1	4.8	3.87	0.00	25	7.34	0.01	45	13.3	0.03	76	23.2	0.08	125	39.0	0.25	199	63.5	0.70	308	100.4	1.83	463
	19.8	10.9	36.8	5.0	1.53	0.00	25	2.90	0.02	45	5.25	0.06	77	9.16	0.19	126	15.4	0.56	200	25.1	1.57	310	39.7	4.11	467
	18.7	11.1	35.5	5.3	0.78	0.01	26	1.48	0.03	45	2.68	0.10	77	4.67	0.32	127	7.86	0.96	202	12.8	2.69	312	20.2	7.05	471
	17.6	11.3	34.1	5.5	0.43	0.01	26	0.82	0.04	46	1.48	0.16	78	2.58	0.50	128	4.33	1.50	203	7.05	4.18	315	11.2	11.0	474
	16.5	11.6	32.7	5.7	0.24	0.02	26	0.45	0.07	46	0.82	0.23	78	1.43	0.75	129	2.41	2.25	205	3.92	6.27	317	6.20	16.5	478
	15.4	11.8	31.2	6.0	0.13	0.03	26	0.24	0.10	46	0.44	0.35	79	0.76	1.13	130	1.28	3.37	207	2.09	9.41	320	3.30	24.7	482
	14.3	12.1	29.6	6.2	0.06	0.04	26	0.12	0.16	47	0.21	0.55	80	0.37	1.76	131	0.62	5.24	208	1.01	14.6	322	1.59	38.4	486
	13.2	12.4	28.0	6.4	0.02	0.07	27	0.05	0.27	47	0.08	0.93	80	0.14	3.01	132	0.24	8.99	210	0.39	25.1	325	0.62	65.8	490
	12.1	12.7	26.3	6.7	0.01	0.16	27	0.01	0.60	48	0.02	2.10	81	0.03	6.77	133	0.05	20.2	212	0.09	56.5	328	0.14	148.1	494

---

[a] Moles NH_3/100 moles H_2O.
[b] Moles SO_2/100 moles H_2O.

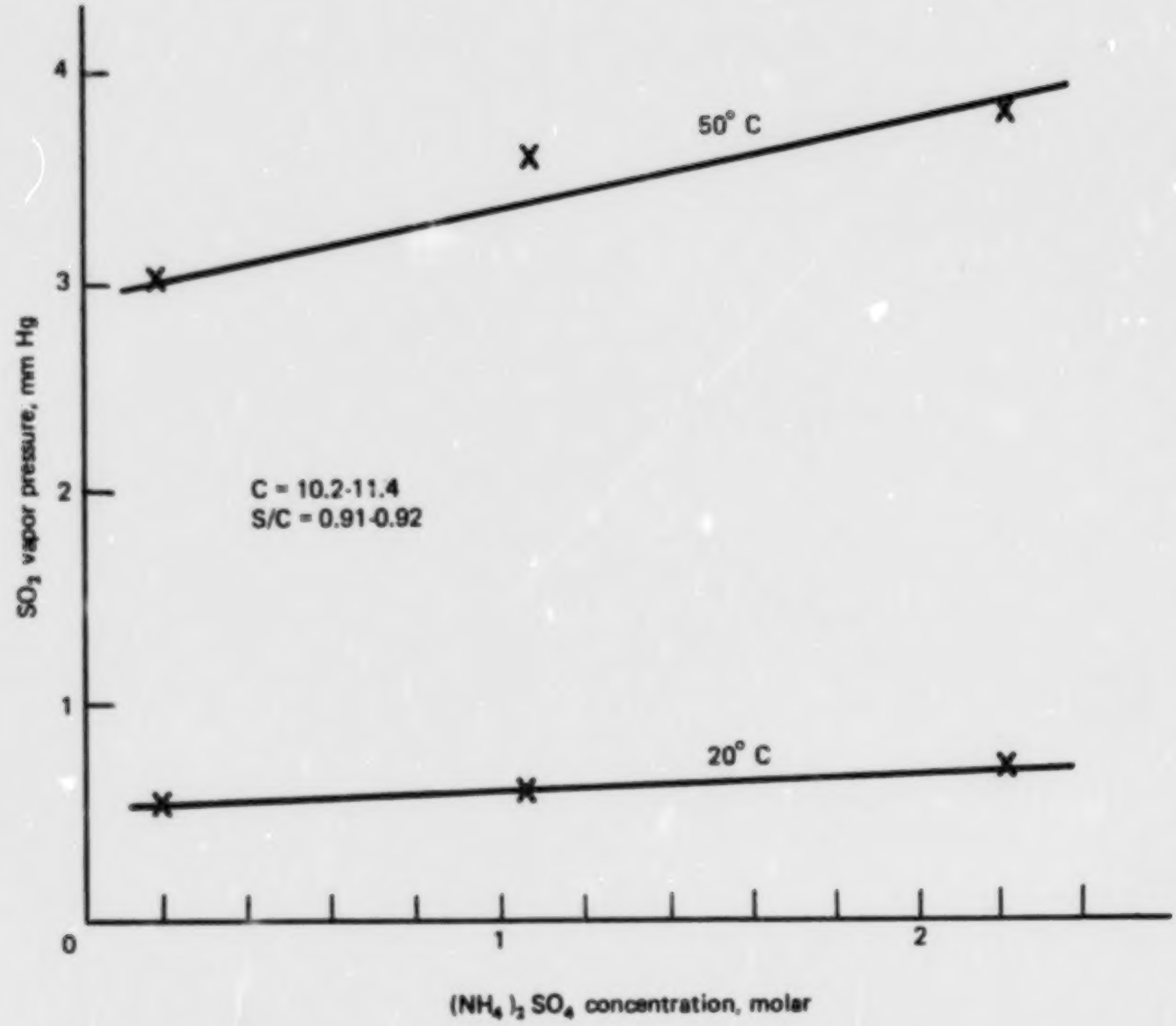


Figure 9. Effect of Sulfate Content on SO_2 Vapor Pressure (23)

Chertkov and coworkers (10) measured pH over a wider range (S/C = 0.5-0.95) than that studied by Johnstone (S/C = 0.7-0.9). They found the same linear relationship in the 0.7-0.9 range and developed a slightly different equation:

$$S/C = 2.22 - 0.25 \text{ pH} \qquad (35)$$

Outside this range, however, the relationship was not linear. The pH reported for pure ammonium sulfite solution was 8.0; values for bisulfite were 3.0 for 5% solution and 2.7 for 45% solution. A curve for pH versus (vs) S/C is shown in figure 12.

Solubility

There have been numerous studies of the system NH_3-SO_2-H_2O but few of the NH_3-SO_2-SO_3-H_2O system actually involved in stack gas scrubbing. The only major investigations of the quaternary system identified in the present study were those of Gottfried *et al.* (Research Institute of Inorganic Chemistry, Czechoslovakia) (37) and Vasilenko (Physico-Chemical Laboratory of the Scientific Institute for Fertilizers and Insectofungicides, USSR) (89). West (94) also has presented information on the quaternary system but his data are calculated from published data on ternary systems. Data from these studies are shown in figures 13, 14, 15, and 16.

Viscosity and Specific Gravity

Chertkov (21) has determined viscosity and specific gravity in the system $(NH_4)_2SO_3$-NH_4HSO_3-$(NH_4)_2SO_4$-H_2O. An equation for partial relative viscosity (Ψ) was developed:

$$\lg \Psi = A\,c\,(1 + BC) \qquad (36)$$

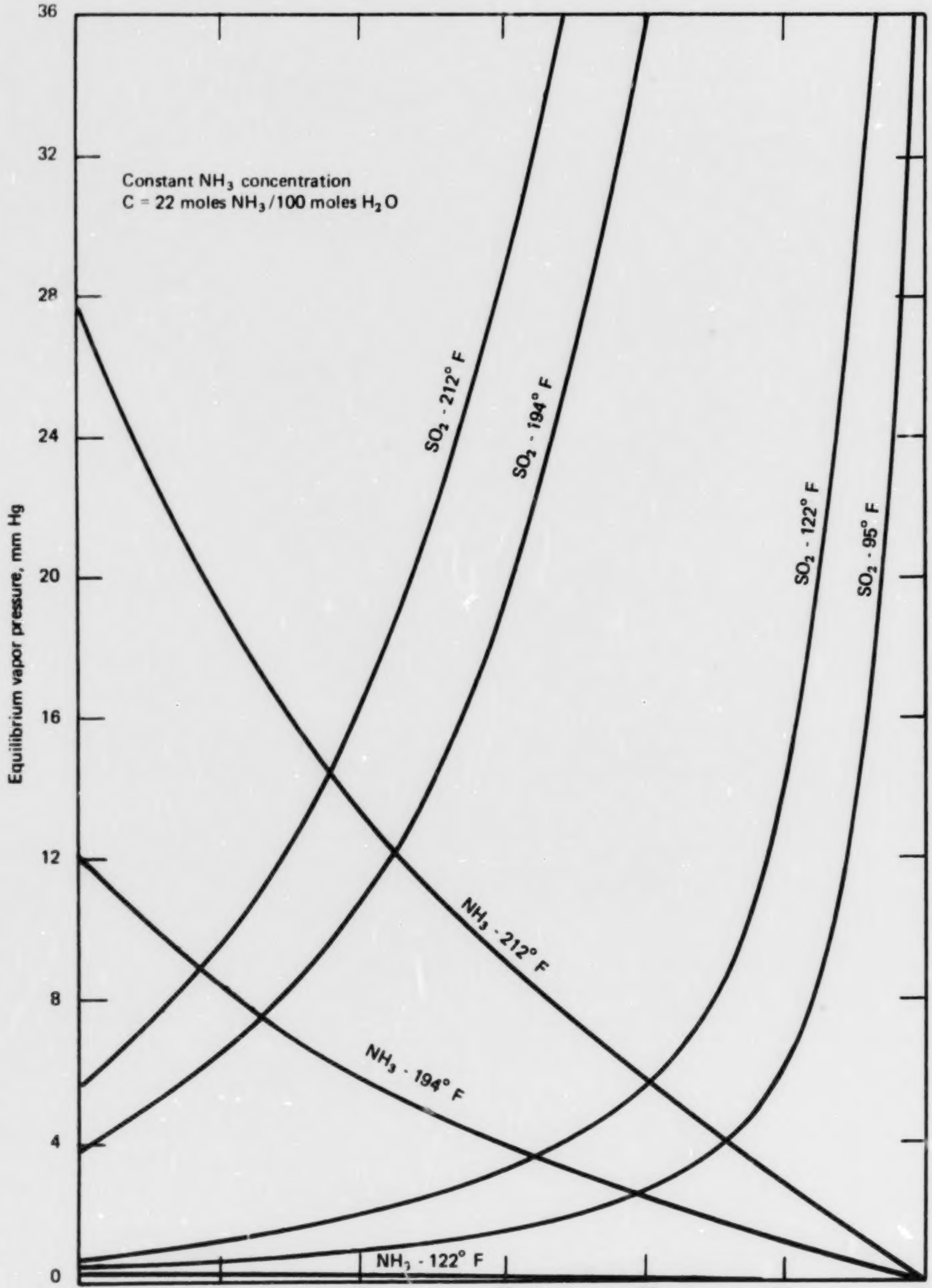


Figure 10. Equilibrium Vapor Pressure Over Ammonium Sulfite-Bisulfite Solutions (94)

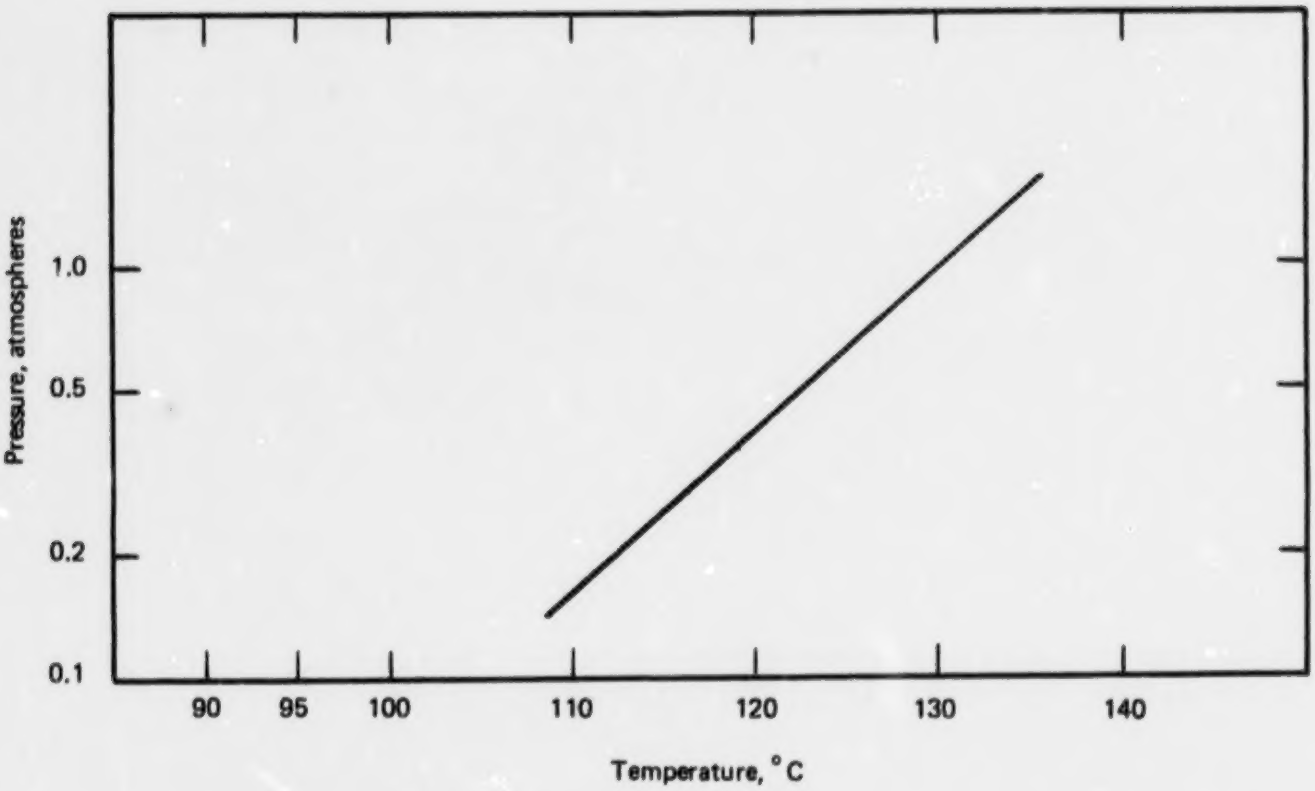


Figure 11. Partial Pressure of SO_2 in the System $(NH_4)_2S_2O_5$-$(NH_4)_2SO_3$-SO_2 (87)

where A and B are constants, c is the concentration [grams-equivalent per liter (g-eq/l)] of the particular salt, and C is the total salt concentration (g-eq/l). Values of the constants for the various salts are given in table 3. The partial viscosity is calculated for each salt and the results added together to give the overall viscosity relative to water.

An expression for calculating specific gravity was also developed:

$$\gamma = 1.0 + a_1K_1 + a_2K_2 + a_3K_3 \qquad (37)$$

where a_1, a_2, and a_3 are component concentrations in grams per milliliter (g/ml) and K_1, K_2, and K_3 are constants. Mean values were used for the constants:

$(NH_4)_2SO_3$	0.482
NH_4HSO_3	0.400
$(NH_4)_2SO_4$	0.474

Kinetics and Mass Transfer

Studies by Chertkov (11) indicate that the chemical reactions involved in absorption of sulfur dioxide by ammoniacal solutions are quite rapid and do not affect the overall absorption rate. The amount of sulfur dioxide absorbed increased linearly with sulfur dioxide concentration in the range 0.08-2% of sulfur dioxide. Thus chemical reactions are not limiting and the mass transfer coefficient is uniform over a fairly wide concentration range.

Chertkov postulates the following reactions for aqueous or alkali scrubbing.

$$SO_2\ (gas) \rightleftarrows SO_2\ (soln) \qquad (38)$$
$$SO_2\ (soln) + H_2O \rightleftarrows HSO_3^- + H^+ \qquad (39)$$
$$H^+ + OH^-\ (\text{from basic absorbing soln}) \rightarrow H_2O \qquad (40)$$
$$HSO_3^- + OH^- = SO_3^= + H_2O \qquad (41)$$

The hydration of sulfur dioxide is regarded as the slowest of these but it is sufficiently rapid to be nonlimiting up to a concentration of 3-4% sulfur dioxide in the gas.

Since sulfur dioxide is quite soluble in ammonia solution, it would be expected that the liquid film resistance to sulfur dioxide transfer would be low. This is true at medium and higher pH levels in the scrubber, but at low pH—such as would be encountered in the first stage of a multistage scrubber—Chertkov found that liquid film

Table 3. Values of Constants A and B for Viscosity Calculations (21)

	Constants	
	A	B
$(NH_4)_2SO_3$	0.065	0.016
NH_4HSO_3	0.036	0.100
$(NH_4)_2SO_4$	0.051	0.015

resistance becomes important. Transfer was eight times as fast at an $SO_2:NH_3$ mole ratio of 0.78-0.82 as at 0.92-0.96 (table 4); the liquid phase resistance was negligible at 0.78-0.82 but was equal to the gas phase resistance at 0.92-0.96.

The transfer rate decreases with increase in temperature. Chertkov (17) found relative rates of 10.2 and 2.32 at 23°

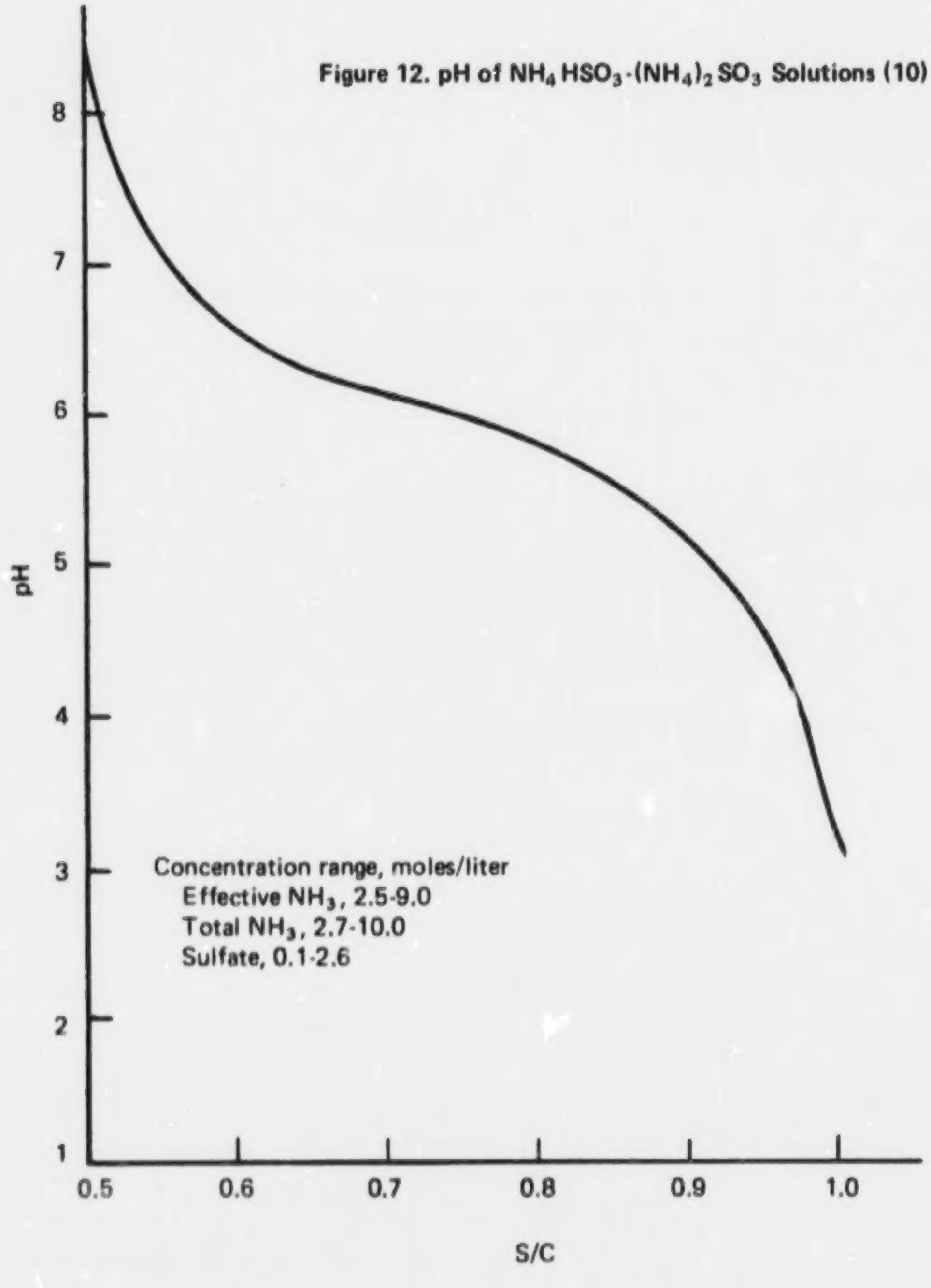


Figure 12. pH of NH_4HSO_3-$(NH_4)_2SO_3$ Solutions (10)

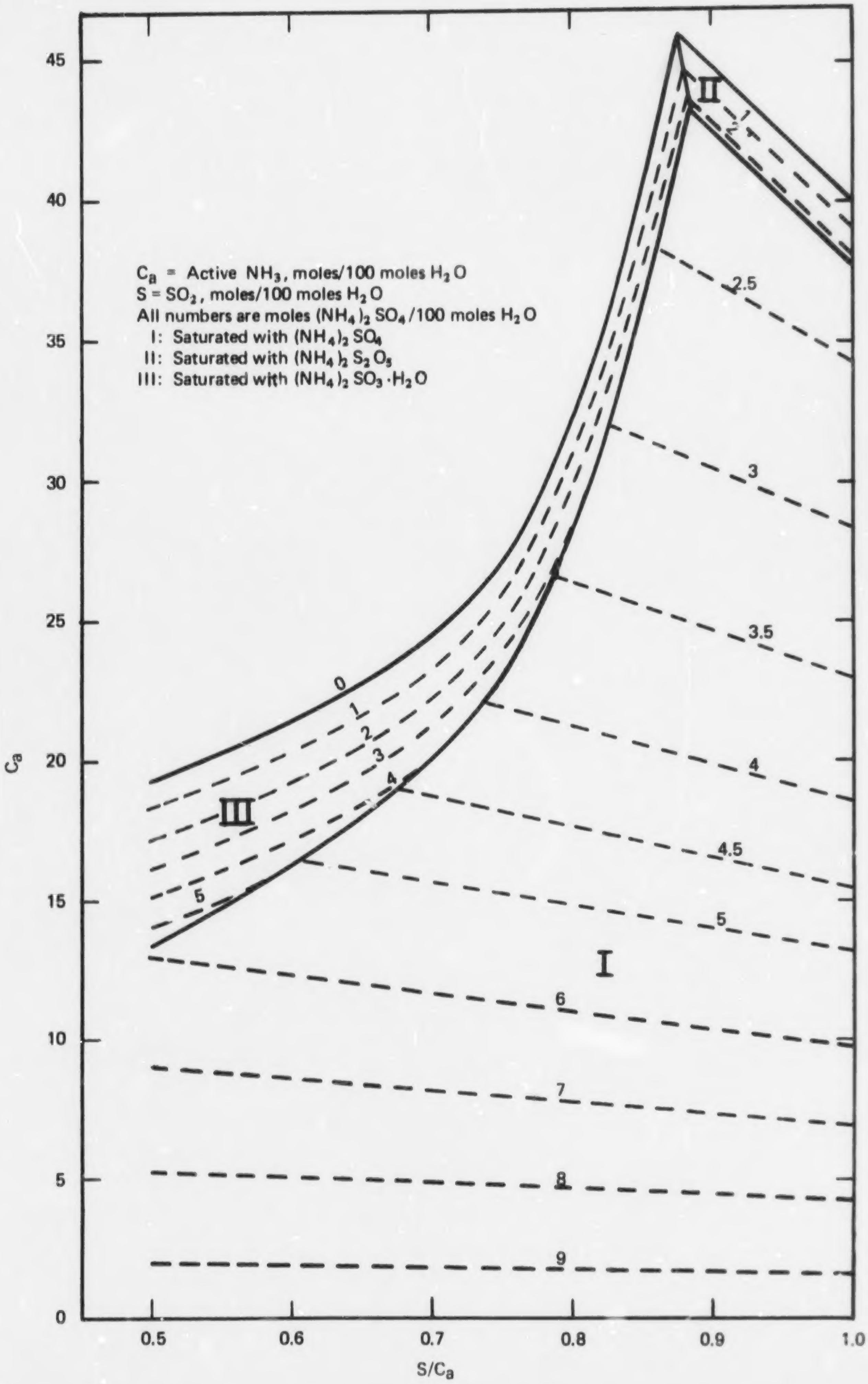


Figure 13. Solubility Diagram for the System NH_3-SO_2-SO_3-H_2O at 86° F (94)

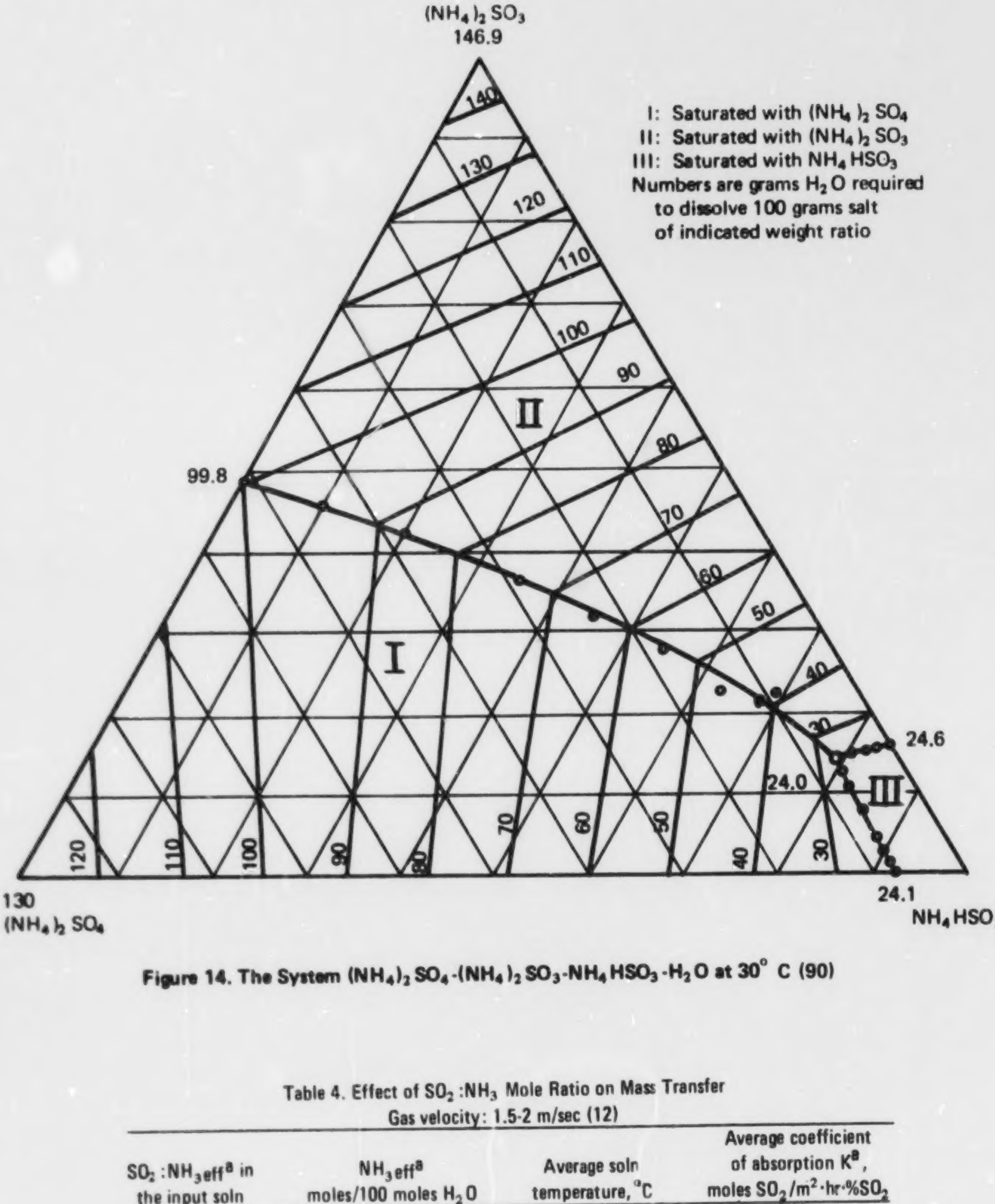

$(NH_4)_2SO_3$
146.9
I: Saturated with $(NH_4)_2SO_4$
II: Saturated with $(NH_4)_2SO_3$
III: Saturated with NH_4HSO_3
Numbers are grams H_2O required to dissolve 100 grams salt of indicated weight ratio
140
130
120
110
100
90
80
70
60
50
40
30
II
I
III
99.8
24.6
24.0
24.1
130
$(NH_4)_2SO_4$
NH_4HSO_3
120
110
100
90
80
70
60
50
40
30

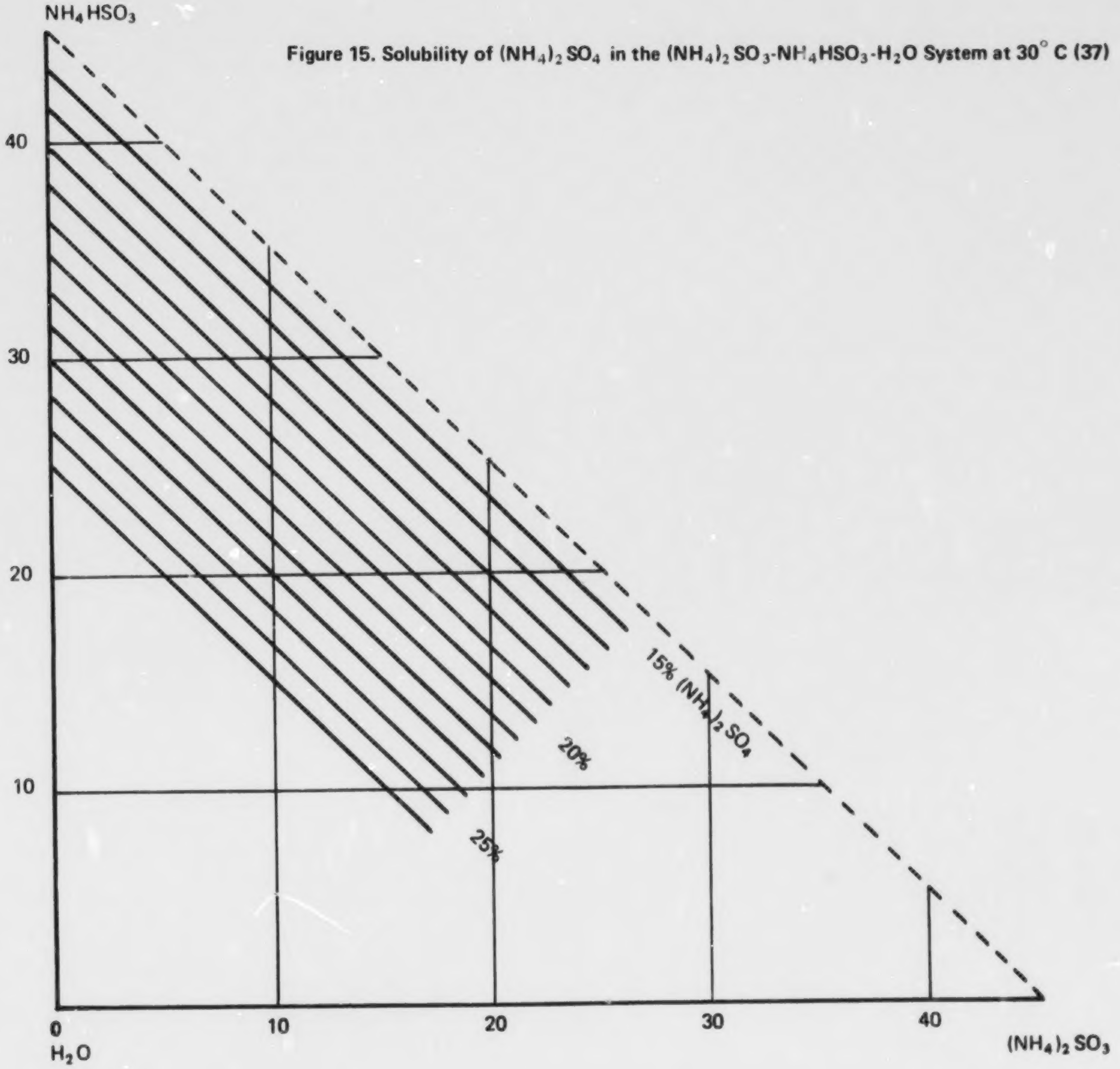
Figure 14. The System $(NH_4)_2SO_4$-$(NH_4)_2SO_3$-NH_4HSO_3-H_2O at 30° C (90)

Table 4. Effect of $SO_2:NH_3$ Mole Ratio on Mass Transfer
Gas velocity: 1.5-2 m/sec (12)

$SO_2:NH_3$eff[a] in the input soln	NH_3eff[a] moles/100 moles H_2O	Average soln temperature, °C	Average coefficient of absorption K[a], moles $SO_2/m^2 \cdot hr \cdot \%SO_2$
0.78-0.82	10	27	1620
0.28-0.84	10	27	1820
0.84-0.86	8.8	30	1320
0.88-0.90	7.6	26	970
0.90-0.92	7.3	26	635
0.92-0.96	5.7	25	200

[a] Effective ammonia is defined as that present in the form of sulfite and bisulfite.

Figure 15. Solubility of $(NH_4)_2SO_4$ in the $(NH_4)_2SO_3$-NH_4HSO_3-H_2O System at 30° C (37)



and 52.5° C. The coefficient was reported to be proportional to the 0.8 power of the linear gas velocity and to the 0.16 power of the solution concentration. Chertkov (18) developed the following empirical equation for the effects of concentration, density, and viscosity.

$$K = \frac{C^{0.16}\gamma^{0.17}}{\eta^{0.4}} \qquad (42)$$

where C is solution concentration, γ is density, and η is viscosity. A small-scale scrubber of the falling-film type was used in the studies.

Chertkov (19) points out that high gas velocity is desirable because the benefit from higher mass transfer more than offsets the cost of the higher pressure drop; he recommends 2.5-2.7 meters per second (m/sec) for a sieve tray scrubber.

Several investigators have found that the contact time required is quite short; Johnstone (47), for example, reported 1-2 sec as adequate for removing 96.7% of the sulfur dioxide from flue gases containing 0.3% sulfur dioxide at 300° F in a grid-packed tower.

Volgin (91) was able to get good absorption even with the short residence time in venturi scrubbers but found it desirable to use several in series to get good sulfur dioxide removal (over 90%) with low pressure drop. He achieved a transfer of 73.1 kilogram per cubic meter-hour-milimeter (kg/m^3-hr-mm) Hg at low velocity and pressure drop (25 m/sec; totalΔP = 14 mm H_2O), and 237 kg at high velocity (60 m/sec; totalΔP = 705 mm H_2O).

The actual transfer coefficients that have been reported vary widely and are difficult to compare because of the differing conditions used by various investigators—type of scrubber, gas velocity, solution composition and concentration, and temperature. For the sieve-tray absorber discussed later in this report, Chertkov (12) found a sulfur dioxide transfer of 14.4 kg/m^3-hr-mm Hg at 2.63 m/sec gas velocity, 33° C, and SO_2:NH_3 mole ratio of 0.82-0.9 (effective NH_3 only). The transfer rate varied widely with gas velocity and temperature.

The transfer rate of oxygen into solution is also important in ammonia scrubbing, as discussed in a previous section. No actual data on the transfer rate were found; however, oxygen is not as soluble as sulfur dioxide and therefore the liquid film resistance should be relatively more significant. Johnstone (44) studied absorption of oxygen and sulfur dioxide in water and found that the oxygen absorption was liquid-film controlled; a bubble-type scrubber absorbed 30 times as rapidly as a spray type. On the other hand, Chertkov (12) compared packed and bubble-type scrubbers and reported that both sulfur dioxide and oxygen absorption were higher for the bubble type; however, the increase was much greater for sulfur dioxide than for oxygen, so that the net effect was less oxidation. It is not clear why the sulfur dioxide absorption, which is controlled by the gas film resistance, should have been improved so much by use of the bubble-type scrubber (however, it was said to be a "foaming" type of perforated-plate operation).

Absorption of sulfur dioxide into water, which would be a consideration in prescrubbing the gas to remove dust, was studied Johnstone (44). The liquid film resistance was found to be 96% of the total [at 4 feet per second (ft/sec) gas velocity]. As would be expected, the absorption rate in a bubble-type scrubber was faster than in a spray type.

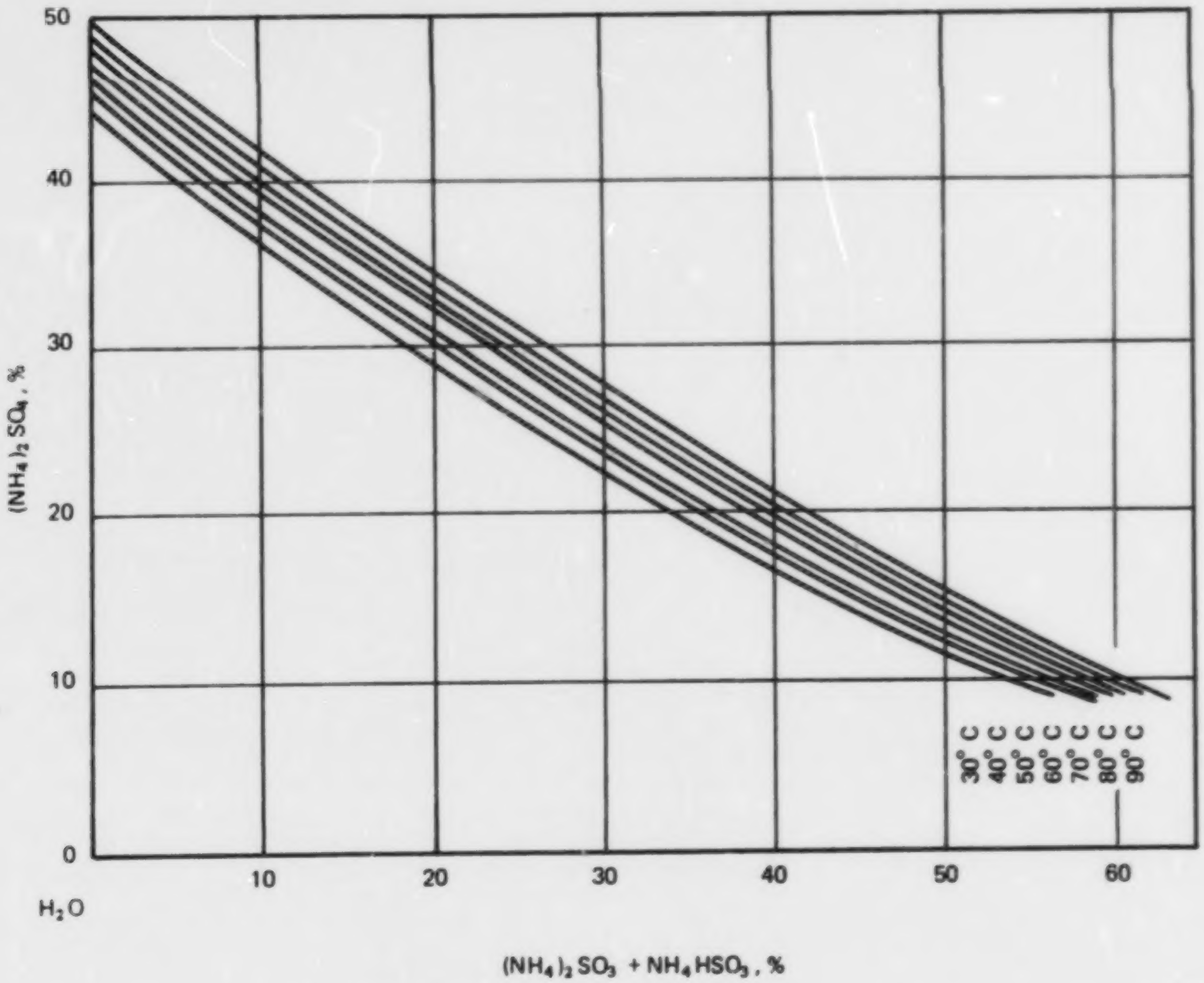


Figure 16. System $(NH_4)_2SO_3$-NH_4HSO_3-$(NH_4)_2SO_4$-H_2O (37)

FORMATION OF AMMONIUM SULFATE

All three of the principal methods for producing ammonium sulfate—oxidation in the scrubber, oxidation of the scrubber effluent, and acidification with sulfuric acid—will be evaluated in the present study. Acidification has some advantage because part of the product is in the form of sulfuric acid, which, as discussed later, is desirable in the fertilizer processes. Oxidation, however, may require less equipment.

Oxidation in the Scrubber

Several investigators have studied the factors affecting oxidation of sulfite or bisulfite during the scrubbing operation, but the emphasis has been on preventing oxidation rather than promoting it. The large excess of oxygen in the stack gas—about 30 times the stoichiometric amount for oxidizing all of the sulfite to sulfate—favors oxidation but it is not known to what degree oxidation could be promoted in the scrubber without interfering with absorption of sulfur dioxide. As pointed out by Johnstone, the net effect of oxidation is to tie up ammonia and thus reduce solution capacity. Thus all the sulfite could not be oxidized to sulfate in the scrubber and still retain absorptive capacity, unless perhaps an additional prescrubbing step were added in which conditions would be adjusted to give oxidation rather than sulfur oxide absorption. This is in effect adding an oxidizer vessel, and a separate oxidizer (described later) may be preferable.

A possible way for carrying out all the oxidation in the scrubber is to cool a side stream and crystallize ammonium sulfate from it, in an amount sufficient to remove the sulfur dioxide absorbed in the scrubber. The amount of sulfate crystallized would also have to be equal to that formed in the scrubber. Hence the rate of oxidation would have to equal the rate of absorption, which might be difficult to accomplish. Perhaps the system would be self-regulating; for example, if oxidation rate were initially not quite as high as absorption, it seems likely that absorption would decrease to an equilibrium level consistent with the solution composition. Or perhaps an operating parameter could be identified that, when varied, would increase absorption and decrease oxidation, or vice versa. Gas temperature or amount of oxidation promoter added might be suitable parameters to vary.

In either case, it would be necessary to promote oxidation to a rate higher than normal. And even if a separate oxidizer were used, it should be desirable to maximize oxidation in the scrubber, to the extent possible without interfering with absorption, so as to reduce the load on the oxidizer. The obvious way to accomplish this is to do the opposite of what researchers have found to be effective ways of inhibiting oxidation.

Chertkov has made extensive studies of oxidation in the scrubber (8, 13, 14, 15, 16, 20). In the last paper of the series, a generalized equation for oxidation rate based on data from several different industrial type scrubbers is presented:

$$G_O = \frac{0.8 \cdot Q^{0.7} \cdot a \cdot (S/C)^6}{\gamma \cdot \mu} \qquad (43)$$

Where G_O = g O_2 absorbed/(hr) (m^2 of liquid-gas contact surface), equivalent to formation rate of ammonium sulfate

Q = liquid flow rate, m^3/(m^2) (hr)

$a = \frac{t}{50}$ where t is the average solution temperature in °C

S/C = molar ratio of sulfur to ammonia in solution

γ = solution density, kg/m^3

μ = solution viscosity, kg-sec/m^2

Study of Chertkov's work leading to development of this equation leads to the following conclusions.

1. Rate of sulfite oxidation depends on rate of oxygen absorption. Therefore, the proportion of the sulfur dioxide input oxidized depends on the relative absorption rates of sulfur dioxide and oxygen. Chertkov's tests showed that maximizing absorption of sulfur dioxide effectively reduced the proportion oxidized because the hydrodynamic factors that increase sulfur dioxide absorption do not have as great an effect on oxidation rate. For example, sulfur dioxide absorption was increased ten to fifteenfold (per unit of scrubber volume) in a bubble-type scrubber (operated under foam conditions) as compared with a packed scrubber. In contrast, the rate of oxygen absorption increased only two to threefold and as a result the degree of oxidation was only about one-fifth that in a packed absorber.

2. Although not emphasized by Chertkov, it is obvious that the $SO_2:O_2$ ratio in the gas has a major effect on degree of oxidation. At low $SO_2:O_2$ ratios, more oxygen goes into solution/unit of sulfur dioxide and as a result a larger proportion of the sulfur oxide is oxidized.

3. Gas velocity is not a factor in oxygen absorption but sulfur dioxide absorption is proportional to the 0.8 power of the linear velocity in an industrial sieve tray scrubber (9).

4. Increase in solution concentration decreases both oxygen and sulfur dioxide absorption. There does not appear to be enough data to determine which is increased more. In any event, economics will probably dictate running at as high a solution concentration as possible.

In several of the investigations, including pilot plant work at TVA (80), dilute solutions have been found to oxidize to a higher degree than concentrated solutions. This supports Chertkov's finding but it should be noted that in many cases this may have been due to the fact that the solution was dilute because it was scrubbing a gas of relatively low $SO_2:O_2$ ratio and therefore a higher proportion of the sulfur dioxide was oxidized (see 2 above).

5. Increase in absorption temperature promotes oxidation but decreases sulfur dioxide absorption.

6. Increase in liquor flow gives faster absorption of both gases. The effect apparently is greater for oxygen absorption.

7. The ratio of sulfur dioxide to ammonia (S/C, mole basis and not including ammonia as ammonium sulfate) is a major factor, possibly the controlling one. Oxidation is a direct function of $(S/C)^6$, whereas sulfur dioxide absorption is affected inversely by increase in S/C (increasing the ratio from 0.78-0.83 to 0.89-0.93 reduced sulfur dioxide absorption by half; for oxidation, such a change should give, according to Chertkov's equation, an increase of about twofold).

It should be noted that Chertkov's papers sometimes are not very clear and in some cases later papers do not seem to agree with earlier ones. With this reservation, the above conclusions indicate that practical conditions for increasing oxidation in the scrubber include (1) high S/C in the solution, (2) use of a packed-type scrubber or some other type that gives a relatively high degree of oxygen absorption compared with sulfur dioxide, and (3) low gas velocity.

The conclusion is that by slowing down sulfur dioxide absorption oxygen will have more time to dissolve, which has the obvious drawback that scrubber cost would be increased. Therefore it might be more economical to minimize scrubber cost by maximizing sulfur dioxide absorption and then do the oxidation in a system specifically designed for it.

An exception to this might be use of an oxidation catalyst. Several catalysts have been proposed. Chertkov (13) reviewed Abel's work on the catalytic effect of thiosulfate $[(NH_4)_2S_2O_3]$ and trithionate $[(NH_4)_2S_3O_6]$ (both are sulfite decomposition products) and proposed a mechanism involving a chain-type reaction of $SO_3^{=}$, $S_2O_3^{=}$, and $S_3O_6^{=}$. Possibly $S_2O_3^{=}$ could be generated in the scrubber solution to serve as a catalyst.

In much earlier work, not connected with power plant gas cleaning, considerable effort went into oxidizing ammonium sulfite solutions as a shortcut in making ammonium sulfate. Vorlander and Lainau (92) reviewed earlier data and reported further work. The main conclusions that can be gathered from this are:

1. Investigators have varied widely in their findings. For example, Vorlander and Lainau state that increase in pH promotes catalysis by metallic sulfates. A pH of 8 was reported as optimum; at pH 5 or less, there was little catalytic effect.

2. A great number of organic substances inhibit oxidation and also interfere with the action of oxidation catalysts.

3. Metal salts exhibiting catalytic activity are Co^{++}, Fe^{++}, Ni^{++}, Cu^{++}, Ce^{++}, Mn^{++}, and V^{5+}.

4. Of these, Co^{++}, Fe^{++}, and Ni^{++} were much the most effective; proportional oxidation rates, respectively, were 100, 50, and 16.

5. The presence of other catalysts was found to impair the activity of cobalt. For example, $CoSO_4$, $CuSO_4$, and an equimolar mixture of $CoSO_4$ and $CuSO_4$ gave relative degrees of oxygen absorption of 15.2, 1.9, and 2.7 (0.9 without catalyst).

Other work on catalysts is found mainly in patents. Yun Kyongshin (58) claims complete oxidation in 18 minutes at atmospheric pressure and 60° C, using CoS, Cr_2O_3, Fe_3O_4, and MnO_2 in a 0.4:0.4:0.4:0.4 weight percent ratio (based on SO_2 content of solution). The use of organic nitrogen compounds (e.g., pyridine and pyridine bases) is claimed by Empresa Auxiliar de la Industria, S. A. (90), Madrid, Spain. A fairly large amount of the pyridine is used and the phases then separated by decantation.

It is not clear whether catalysis would be effective in promoting oxidation in a practical scrubbing operation, if mass transfer is the limiting mechanism as various investigators hold. Most of the tests with oxidation promoters appear to have been carried out on a small scale where mass transfer presumably was not a limiting factor. However, to the extent that liquid film resistance interferes with oxygen absorption, catalysis of oxidation in the solution should be helpful.

Certain general effects may have some bearing on oxidation.

1. Actual stack gas from the burning of coal apparently contains oxidation inhibitors of some sort.

Kashtanov and Ruizhov (55) reported that the inhibitors are phenolic compounds. Hence anything that would neutralize the effect of these inhibitors might promote oxidation.

2. Although the data are not conclusive, there is some evidence that the presence of extensive solid surface in the scrubber promotes oxidation. In carbon adsorption complete oxidation takes place–in contrast to 10-20% in scrubbing with a solids-free liquid. Fly ash may also have such an effect, but since the ash is accompanied by the phenolic inhibitor the effects are difficult to separate. Chertkov (15) postulates that the ash has a catalytic effect that offsets the effect of oxidation inhibitors. The same effect has been noted in working with sodium sulfite solutions; removal of dust before the reaction system sharply reduced the degree of oxidation.

The use of activated carbon placed in the scrubber solution to serve as a catalyst is claimed in a Rumanian patent (75).

3. Tarbutton *et al* (79) at TVA tried the approach of promoting ammonium sulfate formation in an ammonia scrubber by use of catalysts. In preliminary tests with 0.3% Mn^{++} in the solution and 30 parts per million (ppm) of ozone fed into the gas, scrubber solution containing 30% ammonium sulfate removed 75-100% of the sulfur dioxide at a retention time of 18-36 sec. However, the tests were not extensive enough to determine whether oxidation rate equaled sulfur dioxide input rate.

In the Simon-Carves work on the autoclave process (28), a high degree of oxidation was found desirable for control purposes. Manganese sulfate added to increase oxidation was effective, but no data are given on the relative rates of oxidation and sulfur dioxide absorption. The solution also contained 4-11% of thiosulfate, known to be a good oxidation catalyst.

When the Simon-Carves plant was shut down for 3 months, the solution after starting up again was adequately oxidized without use of the manganese sulfate. It was postulated that rusty surfaces or particles in the scrubber were acting as oxidation catalysts.

Oxidation in the scrubber was also studied in TVA pilot plant work (80). The solution composition and $MnSO_4$ addition were about the same as in the Simon-Carves work but the $SO_4^=$ concentration decreased steadily, from 83-6% of the total sulfur, over a 4-day period–indicating an oxidation rate much lower than the rate of sulfur dioxide absorption. The main differences between these and the Simon-Carves tests were absence of thiosulfate and a more concentrated gas (0.3% vs 0.07-0.1%).

In summary, several factors have been identified that can be varied to increase oxidation rate of sulfur dioxide but most of them are either impractical or would be expensive because scrubber size would be increased. The main exception is catalysis, but not enough information is available to determine whether oxidation rate could be increased enough to match sulfur dioxide absorption rate–which would be necessary if ammonium sulfate were the only product and all the oxidation were carried out in the scrubber.

If minimum oxidation were desirable because production of sulfuric acid as well as ammonium sulfate was planned–and maximum yield of acid was desired–then the steps that promote oxidation should be reversed. For most of the factors this would be quite desirable because efficient absorption of sulfur dioxide would be promoted. Oxidation catalysts should be avoided as much as possible; the main one that might occur incidentally–thiosulfate–is not likely to be present in stack gas but could build up in a recycling system because of solution decomposition. Fly ash may or may not be a problem; its effect should be determined.

Oxidation inhibitors also can be used; perhaps a byproduct phenolic waste material can be found that would give adequate inhibition at low cost. The fly ash may be important in this because of Chertkov's finding (see earlier discussion) that the inhibiting effect of p-phenylenediamine is reduced three to fourfold by the presence of fly ash in the scrubber solution. In the absence of ash, addition of 0.01% of inhibitor reduced oxidation from 17-21% to 2%. This was accomplished even though the solution contained up to 0.05 mole/l of thiosulfate.

Because of the oxidation promotion by thiosulfate, it should be much easier to minimize oxidation in a once-through system than in one in which the solution is regenerated, a sulfur product removed, and the regenerated solution recycled. In reverse, oxidation should be much easier to promote in a regenerative system as the thiosulfate concentration should build up to saturation and thus exert maximum catalytic effect.

Another possibility for changing degree of oxidation, either up or down, is to carry out the reaction of ammonia with sulfur dioxide in the gas phase to form a solid product (see earlier discussion under chemistry and kinetics). This would remove oxygen absorption in the scrubber solution as a cause of oxidation but would give oxygen the opportunity of taking part in the gas phase reaction (or of oxidizing the sulfite after it was formed), which might result in more oxidation than in scrubbing. (The latter possibility is supported by the complete oxidation that takes place in the alkalized alumina, Mitsubishi, and activated carbon processes, all of which involve gas-solid interactions; however, these either operate at relatively high temperature or involve very large surface area, in contrast to the Still process where oxidation takes place to a much lesser extent.)

Several investigators have carried out the reaction in the gas phase but few data are available on degree of sulfur dioxide removal or of oxidation. In TVA tests (80), addition of ammonia to saturated gas at the wet-bulb temperature (120-125° F) gave a small amount of solid material together with a saturated or near saturated solution of ammonium sulfite, bisulfite, and sulfate. When gas saturated at 110° F was heated to 120° F (to avoid saturation) and ammonia added, the product was a damp, crystalline material composed mainly of ammonium sulfite monohydrate [$(NH_4)_2SO_3 \cdot H_2O$]—indicating that a solid product can be recovered if the gas is not saturated. (It seems likely that solid product formation would be necessary if reduction in oxidation were desired because operating with saturated gas gives mainly a concentrated solution, subject to the same degree of oxygen absorption as scrubbing with a saturated solution.)

The degree of oxidation was not determined in the TVA tests and reports by others who have studied the gas-gas reaction apparently do not contain such data. Marks and Ambrose (87) studied the reaction of ammonia with sulfur dioxide carried in partially humidified air. Oxidation was relatively low but neither the oxygen nor moisture content were as high as in power plant stack gas.

Oxidation in Separate Vessel

Although it may be possible to operate the scrubber in such a way as to obtain oxidation of the sulfite, such a technique has not been developed and even if it were the scrubber operation might be complicated unduly. Because of this, oxidation in a separate vessel must be considered as the more-or-less established method for converting the entire scrubber output to ammonium sulfate.

As noted earlier, most of the work on separate oxidation has been in connection with efforts to make ammonium sulfate without going through the step of making sulfuric acid. The technology should be generally applicable to the power plant situation, however, as the problem in both cases is that of oxidizing a fairly concentrated solution of ammonium sulfite.

The main difficulty in separate oxidation is getting an adequate rate of oxygen dissolution in the scrubber effluent solution, a problem that has dictated the use of pressure in most of the systems developed. The most complete information obtained in the present study was on the process developed by the Japan Engineering Consulting Company in Japan and engineered by Mitsubishi Shoji Kaisha, Ltd. (42, 43, 66, 96). In this method, solution from the scrubber is neutralized with ammonia (to prevent evolution of sulfur dioxide from NH_4HSO_3 in the scrubber) and then oxidized with compressed air or oxygen atomized into a pressurized, water-cooled reactor. The solution is recycled through the oxidizer and the heat of reaction removed by a cooler in the recycle circuit. Ammonia and sulfur dioxide losses are recovered by introducing the spent air stream into the stack gas before the absorber. The fairly detailed design information obtained on the process has been used in developing the cost estimates presented in a later section of this report.

Of the other development efforts in this area, that of Simon-Carves in England appears to be the most significant. During work by this company on the autoclave process, tests were also made on oxidizing the scrubber solution with air, using a special atomizing device developed by Simon-Carves for another purpose (95). Although good results were obtained, only small-scale tests were made.

Most of the other work is reported only in patents. Bergwerksverband (5) (Germany) describes a process in which the scrubber solution is neutralized with ammonia and oxidized with air or oxygen at 5-25 atmospheres and 150° C. Lonza (61) (Switzerland) claims oxidation at 50° C (presumably at atmospheric pressure) with 10 m^3/hr of air/kg of sulfur dioxide.

A variation proposed by West (94) involves oxidation without first neutralizing the scrubber solution, the objective being to evolve sulfur dioxide from the bisulfite present; in effect this is the same as the acidification method except that the oxidation is carried out in the solution rather than in a sulfuric acid plant. The flowsheet proposed by West (actual tests were not made) is shown in figure 17. A possible advantage is that the relatively high $SO_2:NH_3$ ratio would promote oxidation rate.

Limited tests of such a method have been made at TVA (80); scrubber effluent solution was treated in a packed tower with a countercurrent flow of air. Results were poor, possibly because of insufficient pressure or need to atomize the air into the solution.

Catalysts might also be used to increase the oxidation rate, as discussed in the preceding section.

Miscellaneous oxidation methods include (1) electrolytic treatment of the solution (85) and (2) separation of solid ammonium sulfite from solution by crystallization followed by oxidation of the solid with air at atmospheric pressure.

Acidification

The major work on the acidification process has been done by The Consolidated Mining and Smelting

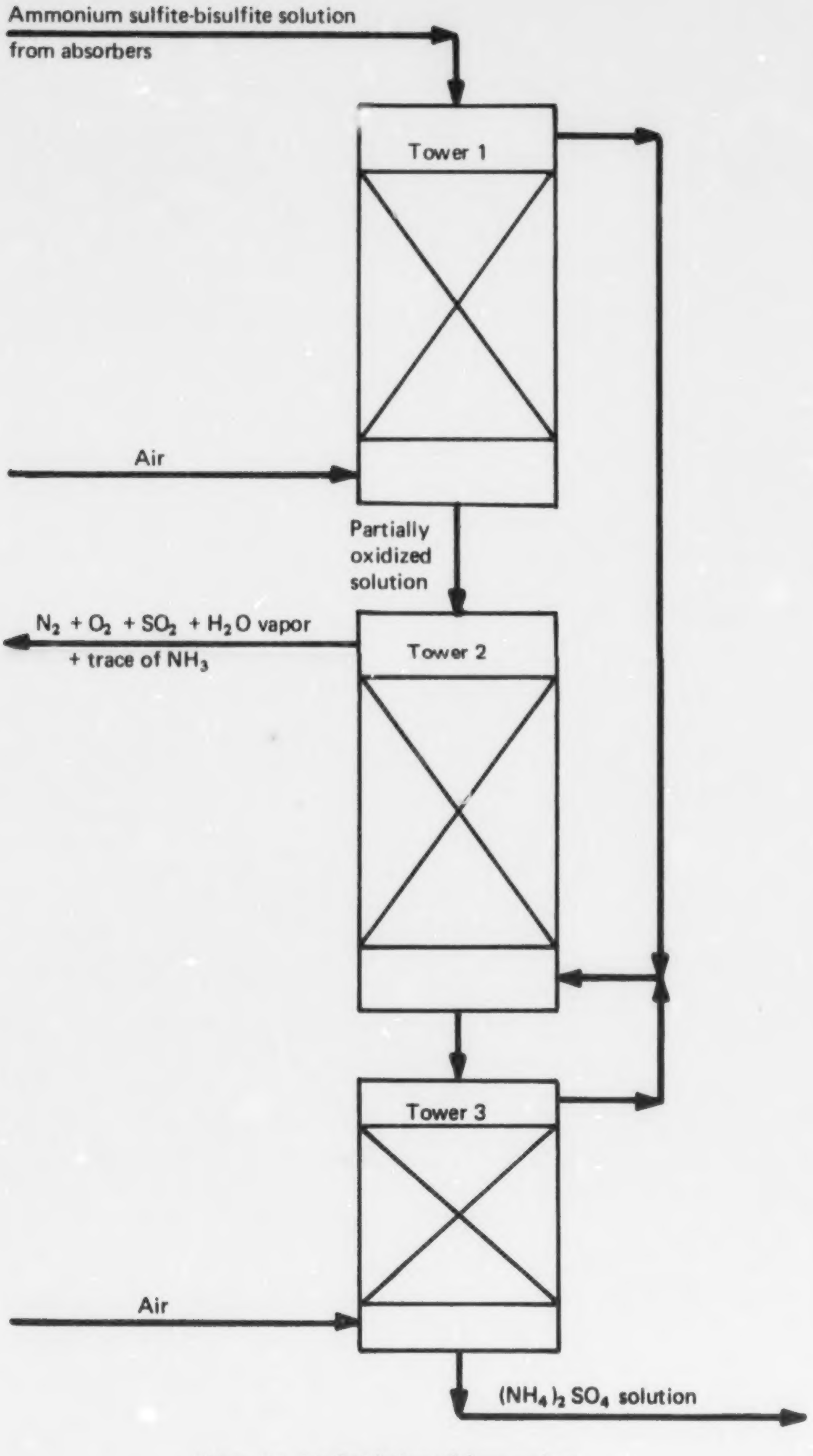

Ammonium sulfite-bisulfite solution
from absorbers
Tower 1
Air
Partially
oxidized
solution
$N_2 + O_2 + SO_2 + H_2O$ vapor
+ trace of NH_3
Tower 2
Tower 3
Air
$(NH_4)_2SO_4$ solution

Figure 17. Air Oxidation of Ammonium Sulfite-Bisulfite Solution (94)

Company (6, 25, 26, 27, 57, 60) (now Cominco, Ltd.) and TVA (59, 69, 73, 80). Johnstone (50) has also given some attention to this system, particularly in regard to adapting the Cominco data, obtained from absorption of sulfur dioxide from smelter gases, to a process for treating power plant gas.

Acidification is a relatively simple process with few problems. Success of the method depends mainly on the scrubbing step which has been discussed earlier.

In the Cominco operation, the scrubber effluent ($SO_2:NH_3$ ratio unknown) is first heated by exchange with the acidifier effluent and then pumped to the acidifier, a brick-lined cylindrical steel vessel fitted with a central air-lift column. Sulfuric acid (93-98%) is pumped through cast iron lines directly into the vessel. Gas evolved by the acid-sulfite reaction provides adequate mixing.

The acidified solution overflows from the acidifier to the top of the "eliminator," a brick-lined steel tower packed with spiral rings through which air is passed to strip out the sulfur dioxide and reduce its concentration to below 0.5 g/l. The air-sulfur dioxide mixture (30% SO_2) is combined with gas that escapes from the acidifier vessel and is then passed to a sulfuric acid plant.

The solution from the eliminator, containing 42% ammonium sulfate, is treated with ammonia to eliminate the acidity of the residual sulfur dioxide and then pumped to an ammonium sulfate crystallizing unit.

Although the TVA work (pilot plant scale) was aimed primarily at working out the problems of the scrubbing step, some acidification tests were made. A residence time of 10-15 minutes (min) was adequate when the liquor was well agitated; about 90% of the sulfur dioxide was evolved during the acidification. The remainder was removed by stripping with steam (600-800 lb/ton of SO_2 evolved) in a packed tower.

In crystallization tests the sulfite content of the ammonium sulfate produced was 0.1% or less (as sulfur); total sulfur was 23.3-24.1% (theoretical for ammonium sulfate is 24.2%). A white product could be made by filtering the solution to remove fly ash (2% of the original ash was caught in the scrubber).

Johnstone has proposed several combinations of acidification with stripping to reduce the heat consumption. Since these apply primarily to the stripping method they will not be covered in this report.

Johnstone points out that the evaporation requirement for obtaining solid ammonium sulfate is independent of the $SO_2:NH_3$ ratio in the scrubber effluent and is a function of the ammonia concentration (figure 18).

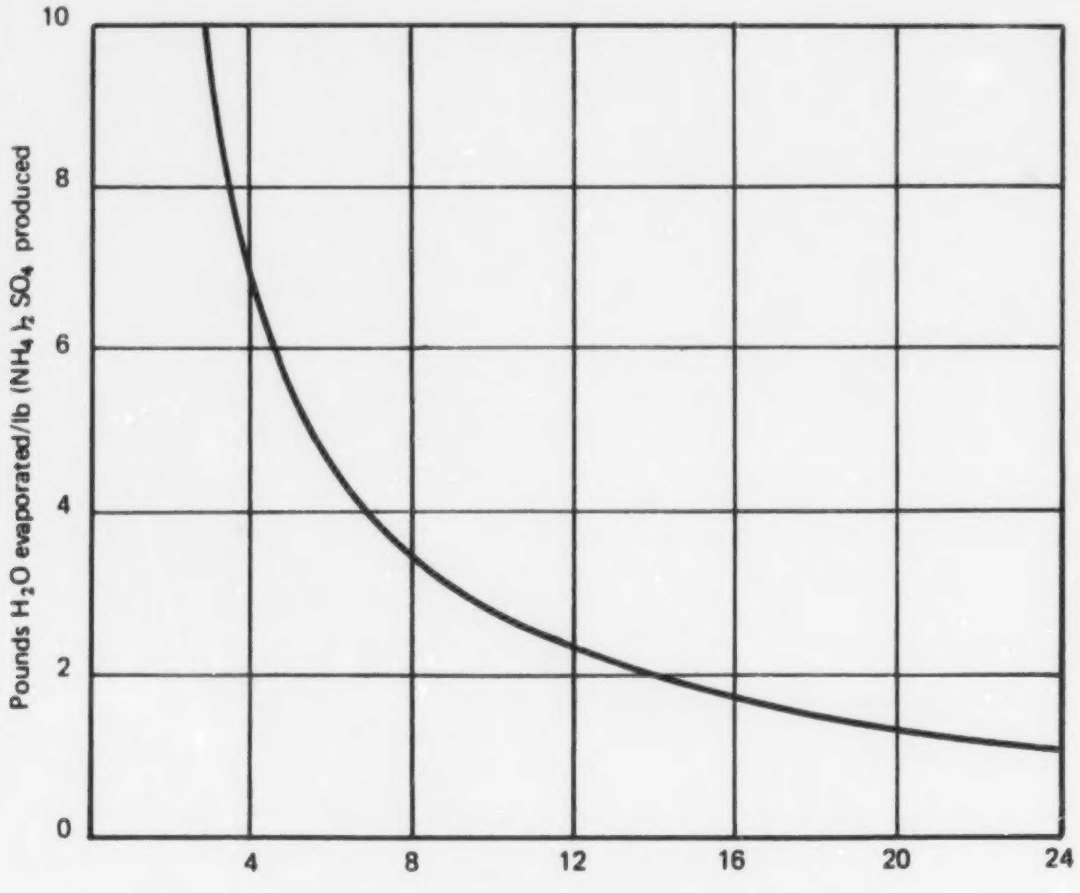


Figure 18. Evaporation Requirements for Production of $(NH_4)_2SO_4$ from Scrubber Effluent (51)

USE OF AMMONIUM SULFATE IN PHOSPHATE FERTILIZER PROCESSES

Ammonium sulfate is an important fertilizer, currently second only to ammonium nitrate in world consumption of solid nitrogen fertilizers and the world leader as recently as 1959. Consumption of ammonium sulfate and ammonium nitrate in 1966 represented 18 and 28% of the world total respectively. Thus ammonium sulfate is losing ground rapidly although the consumption, equivalent to almost 3 million metric tons (mt) of nitrogen/yr, is still quite large.

In the United States the decline has been even more rapid. In the period 1923-1947 ammonium sulfate was the major nitrogen fertilizer and even earlier it was the leading manufactured fertilizer; only natural materials such as sodium nitrate and waste organic products were used in larger quantities. In the past two decades, however, ammonia, ammonium nitrate, and urea, materials of much higher nitrogen content, have moved ahead. Today ammonium sulfate supplies only 577,000 tons of nitrogen (in 1967-1968), less than in recent yrs. Ammonia and ammonium nitrate, on the other hand, supplied 3,338,000 and 887,000 tons of nitrogen in 1967-1968 and have been gaining rapidly.

There are several reasons for this, among them the relatively low nitrogen content of ammonium sulfate and the fact that it does not fit well into some of the modern fertilizer combinations such as liquid fertilizers. Since these considerations are continuing to grow in importance, the future of ammonium sulfate is not bright, at least for the traditional ways of using it—as a straight nitrogen fertilizer or as a constituent of simple mixes.

The processes shown in figures 17 and 18 (pp 41 and 42) are new ways of using ammonium sulfate that appear promising and may improve the status of the material. They are largely untried, however, and there are several questions regarding both technology and economics.

Nitric Phosphate

The nitric acid route to phosphate fertilizer production gained somewhat in popularity in the 1960's because of the generally increasing cost of sulfur (for making sulfuric acid) in this period. (Sulfur price began a decline in 1969 and currently is at a relatively low level.) The problem of removing calcium nitrate from the phosphate rock-nitric acid acidulate slurry (or converting it to something less hygroscopic) has been resolved in several ways; the method being used in most of the new plants involves refrigeration of the slurry to crystallize out the nitrate, an expensive and relatively difficult operation. As an alternative to this, addition of ammonium sulfate to convert the calcium nitrate to ammonium nitrate and calcium sulfate (figure 5, p 21) has considerable promise, assuming that the ammonium sulfate can be obtained at relatively low cost as a byproduct material or by recycling the sulfate.

The comparative economics of these two sources are important in evaluating use of ammonium sulfate from a power plant recovery unit, because a fertilizer manufacturer going into production of nitric phosphate by the ammonium sulfate method would have the choice between obtaining the ammonium sulfate by sulfate recycle or by purchase from the power plant. The power plant product would have to be priced low enough to make it economically attractive as an alternative to recycling.

A flowsheet of the recycle process, as tested recently in a TVA pilot plant, is shown in figure 19. The process consists basically of five steps.

1. Extraction of P_2O_5 from phosphate rock with nitric acid.
2. Removal of calcium from the rock-acid extract by reaction with an ammonium sulfate solution and subsequent filtration of the gypsum formed.
3. Conversion of the gypsum to byproduct calcium carbonate and recycle ammonium sulfate solution by reaction with ammonium carbonate solution.
4. Preparation of the ammonium carbonate solution from ammonia, carbon dioxide, and water.
5. Neutralization, concentration, and granulation of the filtrate from the gypsum filtration step (largely a solution of ammonium nitrate in phosphoric acid).

In steps 1 and 2, unground Florida flotation concentrate (33% P_2O_5, 48% CaO) is reacted with enough 65% nitric acid to give an HNO_3:CaO mole ratio of 2.2 in two extraction tanks arranged in series. Foaming is controlled by the addition of a small amount of antifoam agent (0.1 lb/ton product). Extract from the second extractor overflows to a surge tank where the total retention time is increased to about 2½ hr and supplemental heat is supplied to maintain an extract temperature of about 170° F. The extractor slurry overflows from the surge tank to the precipitator where it is reacted with ammonium sulfate solution. At a temperature of about 160° F, the slurry from the precipitator overflows to a pump feeding the filter. The product filtrate from the filter consists principally of ammonium nitrate and phosphoric acid and is ready for neutralization and concentration, followed by

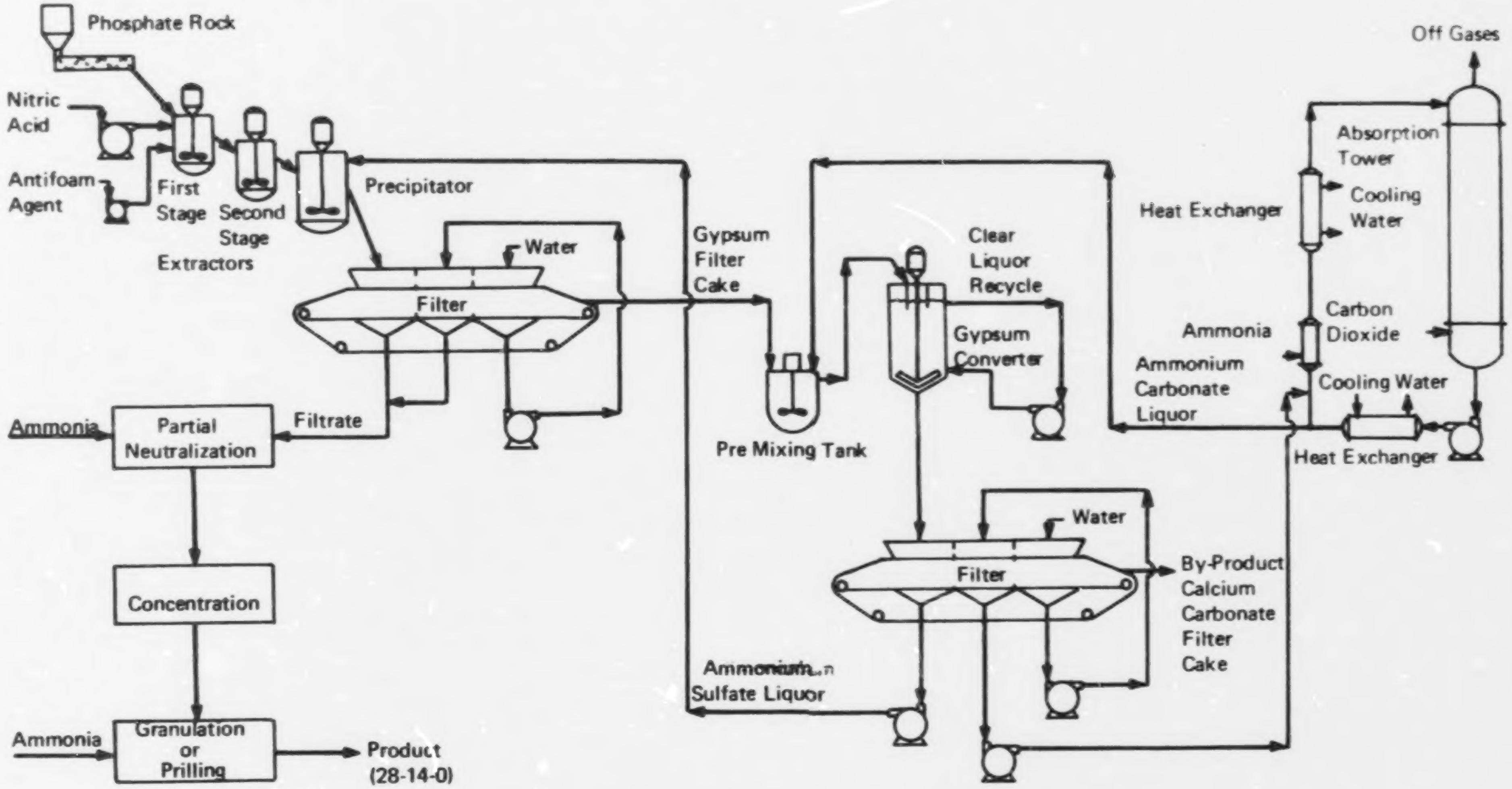

Phosphate Rock
Nitric Acid
Antifoam Agent
First Stage
Second Stage
Extractors
Precipitator
Water
Filter
Filtrate
Ammonia
Partial Neutralization
Concentration
Ammonia
Granulation or Prilling
Product (28-14-0)
Gypsum Filter Cake
Pre Mixing Tank
Clear Liquor Recycle
Gypsum Converter
Water
Filter
By-Product Calcium Carbonate Filter Cake
Ammonium Sulfate Liquor
Off Gases
Absorption Tower
Heat Exchanger
Cooling Water
Ammonia
Carbon Dioxide
Ammonium Carbonate Liquor
Cooling Water
Heat Exchanger

Figure 19. Ammonium Phosphate Nitrate by Nitric Phosphate Route (Sulfate Recycle Process)

granulation or prilling. The gypsum cake is washed countercurrently with water before it is fed to the gypsum converter.

The filter is a horizontal continuous belt type provided with separate filtrate and wash collection systems and a variable-speed drive. Those parts of the filter and accessories in contact with the process materials are constructed mostly of Type 316 stainless steel. The filter medium is a continuous cloth belt of monofilament polypropylene fibers. The filtrate receivers are connected to a wet-type vacuum pump.

The reaction vessels in this section are constructed of Type 316 stainless steel.

In step 3, the gypsum converter is a single-stage unit of unique design developed by TVA. It allows consistent preparation of easily filterable calcium carbonate to overcome a major problem experienced in other processes that use this conversion step (Merseberg reaction). Good conversion efficiency also is obtained. The converter is a mild steel tank with a conical bottom. The working volume is such as to give a 2-hr retention time. Operating depth is about 6 ft with a 1-ft 4-inch (in) freeboard. The converter is equipped with a slow-moving, variable-speed rake to provide gentle mixing and also to keep material from building up over the bottom discharge outlet.

Gypsum cake (directly from the filter) and ammonium carbonate solution are premixed in a small tank (retention time about 2 min) and fed beneath the surface of material in the converter. Supernatant liquid is taken from the top of the converter and recycled to a point near the bottom of the tank to produce an upward circulation. Calcium carbonate slurry is drawn off the bottom of the reactor and pumped to a second filter.

The calcium carbonate is removed by filtration on the second belt-type continuous filter and the ammonium sulfate solution (filtrate) is recycled to the gypsum precipitation step.

In step 4, there are three major pieces of equipment: a packed absorption tower constructed of Type 316 stainless steel, and two water-cooled, shell-and-tube heat exchangers, each constructed of Type 304 stainless steel. The absorption tower has two sections of loosely packed 1-in ceramic Raschig rings. The system is normally operated at a pressure of about 4 pounds per square inch gage (psig). Wash water from the calcium carbonate filtration step is added continuously to the recycled ammonium carbonate solution, and the mixture is then ammoniated, cooled from about 100-85° F, and sprayed onto the top packed section of the absorption tower. Carbon dioxide is introduced through an open end pipe at the bottom of the tower. The solution from the tower is then cooled from 100 to 85° F and a portion is drawn off as product. The remainder is recycled to mix with additional wash water. The synthesized ammonium carbonate solution contains about 34% ammonium carbonate and about 8% ammonium sulfate.

Step 5 is a standard fertilizer operation that is not being tested in the pilot plant. The operation is similar to that presently used in making ammonium phosphate-nitrate products in the TVA full-scale demonstration plant.

If ammonium sulfate from a power plant were used in the process, all the equipment after the calcium sulfate filter would be eliminated and the filter cake would be transported to a disposal pond. The ammonium sulfate liquor would come directly from the oxidizer or acidifier section of the power plant recovery unit and enter the nitric phosphate process at the point shown on the flowsheet. The operation would then be quite simular to that at Dutch State Mines in Geleen, Netherlands, where byproduct ammonium sulfate solution from a caprolactam plant is used (65). The phosphate rock is dissolved in 55-60% nitric acid and ammonium sulfate solution (40%) is added in two steps to precipitate calcium sulfate. The content and ratio of plant nutrients in the product vary with acidulation ratio, $CaO:P_2O_5$ ratio in the phosphate rock, and phosphate water solubility desired in the product.

Ammonium sulfate solution from a power plant should be suitable for the process. The sulfate concentration should be as high as in the Dutch State Mines operation and higher than in the sulfate recycle method (35%). The main question would be in regard to the fly ash content of the solution. In connection with the current study, small-scale tests have been made to determine what effect the dust might have. The results indicate that up to 25% of the fly ash initially present in the gas could be carried along with the ammonium sulfate solution without any major effect on operation; above this the calcium sulfate filtration rate would be decreased. Hence the bulk of the dust would have to be removed by (1) an existing electrostatic precipitator, (2) special scrubbing step before scrubbing with ammonium sulfite, or (3) a filter to remove dust from the scrubbing solution. Any dust carried along to the precipitation step would be filtered out with the calcium sulfate.

One of the drawbacks to the process is that all the nitrogen remains in the product, and as a result the product is relatively high in nitrogen content. In fertilizer terms, the "grade" ranges from about 25-15-0 to 28-14-0 (depending on type of rock and operating conditions), which means that it contains 25-28% nitrogen, 14-15% phosphate (as P_2O_5), and no potash. A grade such as this would have less market potential than the more popular low and medium nitrogen types made by other processes, including the nitric phosphate method in which calcium nitrate is removed by crystallization. In this case the calcium nitrate is converted to ammonium nitrate and sold separately, with the result that the phosphate fertilizer grade is about 23-23-0.

One possibility for reducing the N:P_2O_5 ratio is to treat the scrubber effluent in the power plant by the acidification process and use the resulting coproduct sulfuric acid to replace some of the nitric acid in the nitric phosphate plant. Since the consumption of nitric acid is reduced, the product would contain less nitrogen. The actual grade produced would depend on the amount of sulfuric acid available, which depends on the bisulfite:sulfite:sulfate ratio in the scrubber effluent, as discussed earlier.

Ammonium Phosphate-Sulfate

Although nitric acid acidulation has received much of the attention in the search for ways to eliminate the sulfur requirement in manufacture of phosphate fertilizers, other acidic materials have also been considered. One of these is ammonium bisulfate (NH_4HSO_4), which can be made by heating ammonium sulfate to vaporize one of the ammonium radicals from the molecule.

Use of ammonium bisulfate to decompose phosphate rock was proposed in patents as early as 1918 (35), but apparently the only useful data are those developed in the USSR by Karakhanyan *et al* (38, 52, 53, 54, 63). There are a few other papers and several patents on the subject but most of these deal with production of a solid, superphosphate-type product (12-18-0). The process evaluated in the present study differs from this in that (1) enough ammonium bisulfate solution is used to produce phosphoric acid rather than monocalcium phosphate and (2) the product slurry is filtered to separate and remove the calcium sulfate rather than leave it in a solid, superphosphate-type product.

The phosphoric acid type of process was mentioned in an early news item (1927) that reported development of the method in work at the University of Alabama sponsored by the Alabama Power Company (2). It was said that a practicable and economical method had been worked out but no data were given. The report stated that construction of a manufacturing plant was being planned. Apparently the plant was never built.

The only other work of this type identified in the present survey is reported in the papers by Karakhanyan *et al*. Good dissolution of the phosphate rock, up to 98%, was obtained. The main difficulty apparently was formation of a double salt, $5CaSO_4 \cdot (NH_4)_2SO_4 \cdot H_2O$, that caused some loss of nitrogen by retention in the filter cake. The loss was reduced to 3% of the nitrogen by washing the cake with dilute sulfuric acid.

To further explore the process, small-scale tests have been carried out at TVA (81). Phosphate rock was treated with hot (150-200° F) ammonium bisulfate solution, the resulting slurry mixed for a period, and the precipitated calcium sulfate filtered off. Various mole ratios of NH_4HSO_4:CaO were tested; for the ratios 1.6, 1.86, and 2.0, 1.86 gave better phosphate (P_2O_5) recovery (94%) from the rock than did 1.6 and as good recovery as for 2.0. Dissolution of the rock was essentially complete; most of the unrecovered P_2O_5 was present in the filter cake as a citrate soluble but water insoluble form, indicating that it was reprecipitated dicalcium phosphate such as is normally found in the gypsum cake from standard wet-process phosphoric acid operations. Addition of a small amount of sulfuric acid to the ammonium bisulfate solution did not reduce the P_2O_5 loss in the cake.

The product grade from these tests, after ammoniation and granulation of the filtrate (phosphoric acid plus ammonium sulfate), was approximately 18-18-0.

Work has also been done at TVA on the step of converting ammonium sulfate to ammonium bisulfate. It is reported by Ross *et al* (74) that the conversion takes place at about 570° F. In TVA tests to confirm this and to explore procedures, heating at 600° F gave very slow conversion. About 94% of the ammonium sulfate was decomposed after heating at 750° F for 1¼ hrs in the presence of a sweep gas to remove the evolved ammonia. Infrared and X-ray examination indicated that diammonium pyrosulfate [$(NH_4)_2S_2O_7$] was formed rather than ammonium bisulfate. The material dissolved easily in water, however, and evaporation of the resulting solution gave ammonium bisulfate.

These tests and the work reported previously indicate that the overall process should be technically feasible. Further small-scale work and pilot plant tests would be necessary, however, as steps in the further development. Some increase in rate of ammonium sulfate decomposition to bisulfate is desirable and might be obtained in equipment designed for faster removal of evolved ammonia. A corrosion test program is also indicated.

In the phosphate acidulation step, it would be desirable to reduce the citrate-soluble P_2O_5 content of the cake, which might be done by use of a countercurrent washing procedure such as used in the standard wet-process phosphoric acid method. The problem of nitrogen loss in the cake by double salt formation, reported by Karakhanyan *et al*., and not checked in the TVA tests, also should be explored further.

MAJOR ECONOMIC CONSIDERATIONS

The present study is the first one in the series that involves sale of a product and therefore new problems such as profit margin, product marketability, and projected financial attractiveness are introduced. These factors cannot be ignored—as some have proposed—on the basis that the need to reduce pollution justifies any financial loss that may be incurred in a recovery process; the limestone-wet scrubbing method is an example of a reasonable alternative that sets a minimum operating cost penalty for pollution control, beyond which any loss from a recovery operation is not justified.

Cost of Alternative to Recovery

Data on the cost of limestone-wet scrubbing as the alternative to recovery are available from the previous NAPCA-TVA conceptual design study (83). In setting a basic cost figure for comparing with a recovery process, most of the variables, e.g., size of plant, sulfur content of fuel, capacity factor, new versus existing plant, and degrees of sulfur removal and reheat, can be set at the same level for the two processes. An exception is cost of limestone, which may vary considerably between plant locations. However, the limestone cost used in the design study ($2.05/ton, delivered, -½ in) is believed to be typical for most parts of the country.

For convenience, the summary tables for investment and operating cost given in the limestone-wet scrubbing report are repeated here (tables 5 and 6).

Return on Investment

One of the major drawbacks to recovery processes is the higher investment as compared with the limestone methods. This not only increases cost items such as depreciation, insurance, and taxes, but also intensifies the effect that projected return on investment has on the economic attractiveness of the process.

In the limestone-wet scrubbing study, it was assumed that (1) the investment would be half debt and half equity, (2) the debt capital would earn only enough to pay the interest, (3) the equity portion would earn at 11% of average undepreciated investment, and (4) the plant would be depreciated over a period of 35 yrs. This seems to be a fair average of the capital structure and rate of return in the utility industry, although there is considerable variation among companies (32).

It can be said that no return on equity should be expected from a pollution control unit. However, the investment for the sulfur dioxide removal equipment would almost certainly be merged with the total power plant investment as is that for dust-collection equipment, and would therefore increase the "rate base" on which the utility is allowed to earn at the rate set by the regulatory commission. Thus the return on equity must be included in any process comparison; it is the "cost of money," as essential as any other cost item.

Table 5. Capital Cost of Limestone - Wet Scrubbing (83)

Conditions	Capital, $/kw of power capacity
Base case[a]	13.05
Exceptions to base case	
2.0% S	11.70
5.0% S	14.30
Limited reheat[b]	
To 200° F	10.52
To 175° F	9.47
Process B[c]	13.80
Process B (with lime)[d]	20.00
500 mw	10.85
1,000 mw	8.21
1,000 mw, process B	8.82
1,000 mw, new power unit[e]	6.32

[a] Base case assumes 200-mw unit, existing power plant, 3.5% sulfur in coal, process A (injection-scrubbing), reheat to 250° F by heat exchange, 99.5% dust removal, 95% SO_2 removal, and nonrecycle of sluice water.

[b] Reheat by direct firing natural gas.

[c] Addition of limestome to the scrubber circuit; 85% SO_2 removal.

[d] Addition of lime (CaO) to the scrubber circuit.

[e] Includes credit for eliminating electrostatic precipitator.

When a recovery process is considered on this basis, certain complications arise. In the first place, recovery is a chemical enterprise and the chemical industry differs radically from the utility industry in financial practice, particularly in evaluating new projects and attracting investment for them. Because of the usual risk involved, chemical producers generally require a fairly short projected "payout" period before going ahead with a project: the "cash flow" (depreciation plus net profit) expected must be high enough to return the total investment in, say, 4-6 yrs. Sometimes the gamble is unsuccessful, of course, so that the actual average payout in practice is somewhat longer, about 7.5 yrs for the basic chemical industry (34).

In contrast, the payout period in the utility industry, calculated for the assumptions listed above, is about 13.5 yrs—a figure that is borne out by published data on actual performance of the industry, which show a cash flow of about 7.5% of original investment, or a payout of 13.3 yrs (32). The reason that investors continue to finance power plants with such a long expected payout period is that little or no risk is involved. The price of the product is regulated, by governmental commissions, within limits that average out to give such a return.

Thus if the investment for sulfur dioxide recovery is made part of the utility rate base and the usual rate of return allowed, the prospect for economic feasibility becomes considerably brighter. If the usual chemical industry payout were required, about $35/ton of sulfur equivalent in the product would be needed to take care of the cash flow alone (assuming 5-yr payout, 4% S in coal, $15/kilowatt (kw) investment for the recovery process, and 70% capacity factor for the power plant). For utility type of financing, this figure would drop to $13/ton.

Table 6. Operating Cost for Limestone - Wet Scrubbing (83)

Conditions	$/ton of coal	Mills/kwh
Base case[a]	1.31	0.49
Exceptions to base case		
2.0% S	1.05	0.39
5.0% S	1.57	0.59
$1.00/ton limestone	1.17	0.44
$4.00/ton limestone	1.56	0.59
Intermittent operation[b]		
720 hr/yr (30 days)	0.75	0.28
4,000 hr/yr (½ yr)	1.18	0.44
Reduced boiler operation[c] (50% load factor)	2.10	0.79
Limited reheat		
To 200° F	1.13	0.42
To 175° F	1.06	0.40
Intermittent reheat to 200° F[d] (30 days/yr)	1.07	0.40
Sluice water recycled	1.33	0.50
Process B[e]	1.42	0.53
Process B (with lime)[f]	1.85	0.69
500 mw	1.11	0.41
1,000 mw	0.90	0.34
1,000 mw, process B	0.99	0.37
1,000 mw, new power unit[g]	0.76	0.29
1,000 mw, new power unit, $1.00/ton limestone	0.64	0.24

[a] Base case assumes 200-mw unit, existing power plant, 3.5% sulfur in coal, 8,000 hr/yr operation, process A (injection-scrubbing), nonrecycle of sluice water, reheat to 250° F by heat exchange, $2.05/ton limestone cost, 14.5% capital charge, 99.5% dust removal, and 95% SO_2 removal.

[b] Boiler operating at full load; scrubber operating for period shown; cost is average based on all coal burned and power produced/yr.

[c] Boiler operated intermittently or at reduced load; scrubber operated when boiler is in operation.

[d] Direct heating with natural gas.

[e] Addition of limestone to the scrubber circuit; 85% SO_2 removal.

[f] Addition of lime (CaO) to the scrubber circuit.

[g] Includes credit for eliminating electrostatic precipitator.

From contacts made in the course of this study, it appears that power companies generally will favor making the sulfur dioxide recovery investment part of the rate base. It can be argued that this would work a hardship on companies that recover sulfur or make sulfur products in the unregulated chemical and metallurgical industries, where there is no regulation of price and therefore no guarantee of return on investment. Because of the low risk in the regulated utility industry, sulfur dioxide recovery may be economically feasible where otherwise it would not be—and thus large amounts of sulfur (or sulfur products) could come on the market that otherwise would not be there. As a byproduct it would be sold at whatever price required to move it and therefore could present formidable competition to the established sources.

The effect of this aspect of the situation on the methods finally adopted for financing sulfur dioxide recovery units is difficult to assess. Another factor that may be important is the general reluctance on the part of most power companies to enter into the chemical field. Probably the most practical arrangement in this respect is operation of an absorption unit by the power company and transporting of the loaded absorbent "across the fence" for regeneration or conversion by a chemical company. Although this would be a convenient arrangement, the requirement on the part of the chemical company that there be an acceptably short projected payout for its part of the investment would remain as a major economic obstacle.

Another alternative would be for the power company to contract with a chemical company to provide all the facilities and service required for recovery of sulfur dioxide. This would be advantageous for the utility because no investment would be required and the cost for pollution control could be firmly fixed. However, the larger investment by the chemical company, as compared with the across-the-fence situation, would make projected payout even more of a deterrent to investor acceptance.

Because the most likely mode of ownership and operation is not clear, economics in the present study will be developed for all three approaches: (1) all power, (2) joint venture, and (3) all chemical.

Power Plant Capacity Factor[2]

Recovery of sulfur oxides combines power generation and chemical production—two very different types of operation. The power plant cannot store its product as can most chemical operations, and since the demand for electricity is quite variable the plant must be designed for rapid change in production rate and must operate at less than full capacity for a good part of the time.

Moreover, power plants are usually operated on a system basis; several plants distributed over a service area are operated as an integrated system to supply the power demand, peak as well as average, in the most economical way. In many cases a computerized control system is used to analyze the demand pattern and to assign the load to those plants that can most economically supply it to the points of use. Thus some plants are operated at full capacity a good part of the time, some operate only at part capacity much of the time, some operate only at peak system load, and some are standbys that operate only in case of primary plant breakdown or other emergency. The range in individual plant load factor depends on the variation in system load, which differs between systems because of geographical variations in use pattern. A typical weekly load curve for the TVA system is shown in figure 20 and an annual curve in figure 21.

Historically, new generating units added to a power system have been larger, more efficient, and more economical to operate than units already in service. It follows then that the newer units get the most use and that the dispatch system operates the less efficient plants only when necessary. Then as the new units grow older they in turn are pushed into peak load or standby status by even newer and more efficient units. The following is a typical load factor sequence over the life of a boiler unit.

Years	Average annual capacity factor, % of full load
0-10	80
11-15	57
16-20	40
20-35	17

The average capacity factor over the 35 yrs is about 43%.

Thus capacity factor becomes an important consideration in evaluating the cost of sulfur dioxide removal over the life of the plant. For example, the cost of limestone-wet scrubbing in table 6 is $0.76/ton of coal burned for a 1000-mw unit operating 8000 hr/yr (assumed unit availability), whereas at 43% capacity factor (equivalent to 3760 hr) the cost is $1.34/ton of coal. At the lower capacity factor, there are fewer tons of coal over which to spread the capital costs.

The effect of the expected future low capacity factor on the decision to enter into a sulfur dioxide recovery project is difficult to evaluate. In the chemical industry the first few years of operation are the important ones; the situation 20 or more yrs in the future is seldom considered. This makes capacity factor less important because the factor in the first few yrs is relatively high. The low factors come in the future, beyond the period considered in planning. Perhaps the main consideration would be the practicality of operating a recovery unit at very low capacity factor, even if no profit were expected because a satisfactory total return had been obtained in the early years of operation. The cost of maintaining a crew for intermittent operation and problems in marketing the sporadic production might make it expensive to continue recovery merely to control pollution.

A utility presumably would give more attention to the entire life of the unit in evaluating the effect of declining capacity factor on recovery of capital and return on capital. Since depreciation is a uniform annual capital charge, the net effect would be higher income/unit of production in the early yrs than in the later ones. However, the proceeds needed in the later yrs is lower because there is less undepreciated capital remaining in the project. Moreover, the effect of any decline in proceeds in the later yrs is minimized by the fact that the present worth of dollars that far in the future is relatively low.

It is concluded that declining capacity factor is not as much a drawback as it might seem, at least as far as capital charges are concerned. Operating cost and product marketability, however, may be major problems at the 10-25% capacity factors typical in plants over 15 yrs old. These problems might be avoided by combining gas flow from adjacent boilers to keep the recovery unit operating or by switching to limestone scrubbing and shutting down the fertilizer system.

Notwithstanding these considerations, incorporation of sulfur dioxide recovery into a power plant during construction should generally be more economical than adding recovery facilities to an existing one. In addition to reduced capital cost (because of better integration of the two units), there will be more total kwh over which to spread the capital charges—which is an important consideration even though the effect of reduced production is minimized because it occurs in the later yrs.

---

[2] *Capacity factor* is plant output as percentage of nameplate capacity. *Load factor* is plant output as percentage of unit capability (after substraction of time for maintenance and repair).

Even in the early yrs, however, the capacity factor is not ideal. Even though new generating units are usually assigned a base load status, they do not necessarily have high load factors because at times other factors such as location and cost of fuel may favor shifting of load to some of the older plants. Moreover, problems that develop during initial operation of new units often require additional outage time for modification and therefore reduce the availability of the unit.

This is quite undesirable for a chemical operation; chemical products can be stored and the usual practice is to operate the production unit as continuously and uniformly as possible, with swings in product demand offset by using storage as a buffer. The plant may be slowed or shut down completely for a period if storage becomes a problem. Operation in conjunction with a power boiler, with wide swings in production rate, would be expensive and for some processes quite difficult to accomplish.

In some sulfur oxide recovery situations it may be practical to use a holding system for loaded absorbent as a buffer between the absorption and finishing steps, so that only the absorber operation would have to vary with the power plant capacity factor. Or the recovery unit might be designed for only partial sulfur oxide removal, where pollution regulations permit, so that even at reduced boiler load there would be enough sulfur throughput to keep the recovery unit running at capacity. These alternatives have been discussed by J. E. Newell (Central Electricity Generating Board, England) (70).

Sulfur Content of Coal

A major economic advantage for recovery is that high sulfur content of the coal works in its favor, whereas the opposite is true for limestone-wet scrubbing. Most estimates of process cost have assumed a sulfur content

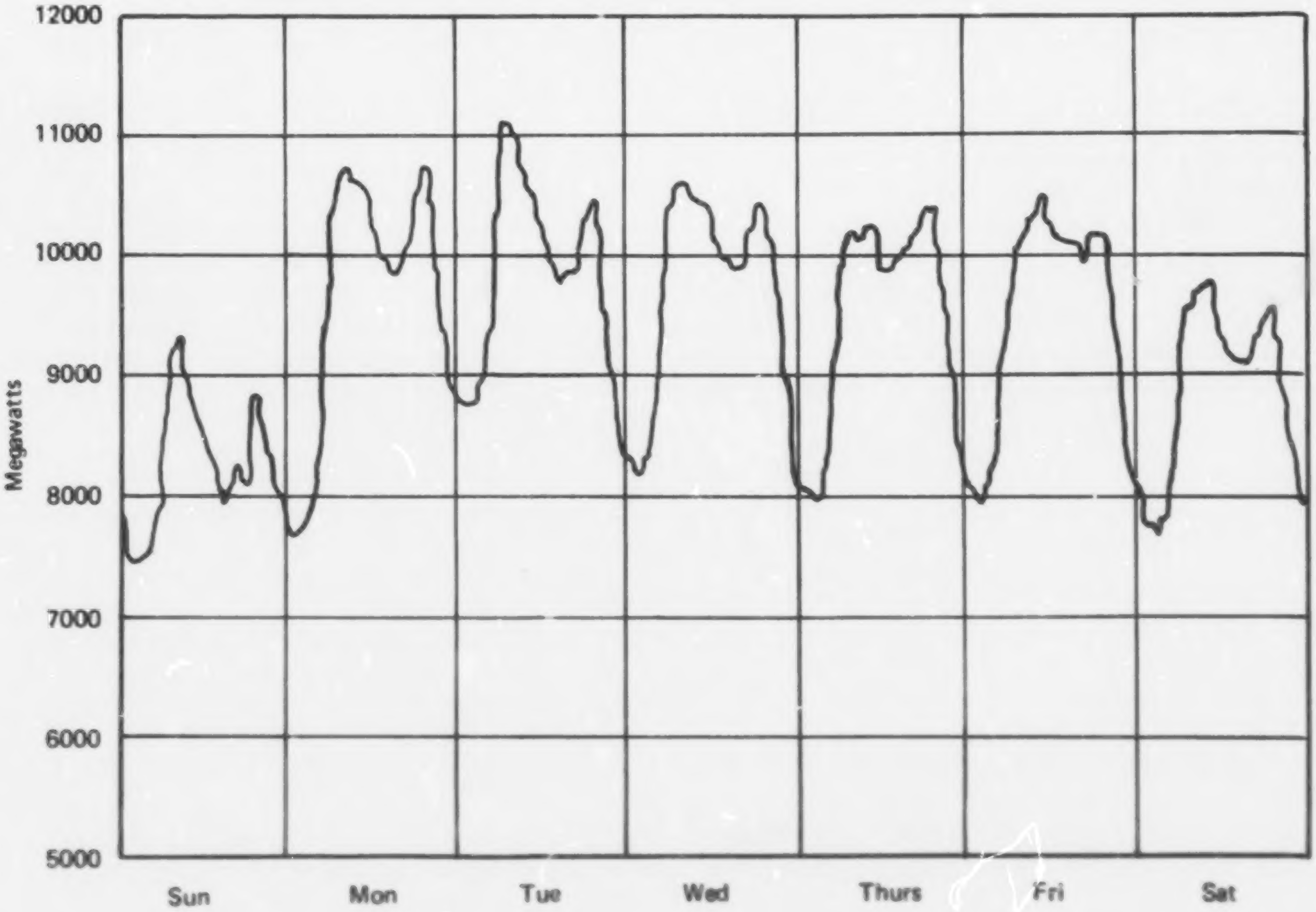


Figure 20. Typical Weekly Load Curve for TVA Power System (Spring 1968) (84)

of 3-4% but large quantities of coal containing more than 4% are mined, particularly in Illinois, Ohio, Missouri, and western Kentucky (71).

In a recovery-type process, use of high-sulfur coal would give considerable economy in regard to equipment sized on the basis of gas flow rather than sulfur throughput. Thus processes in which all equipment must handle the full gas stream are benefited the most. In contrast, wet-scrubbing processes require gas flow only through the scrubber and the size of the rest of the unit must be increased for higher sulfur throughput. There is some economy of scale but much

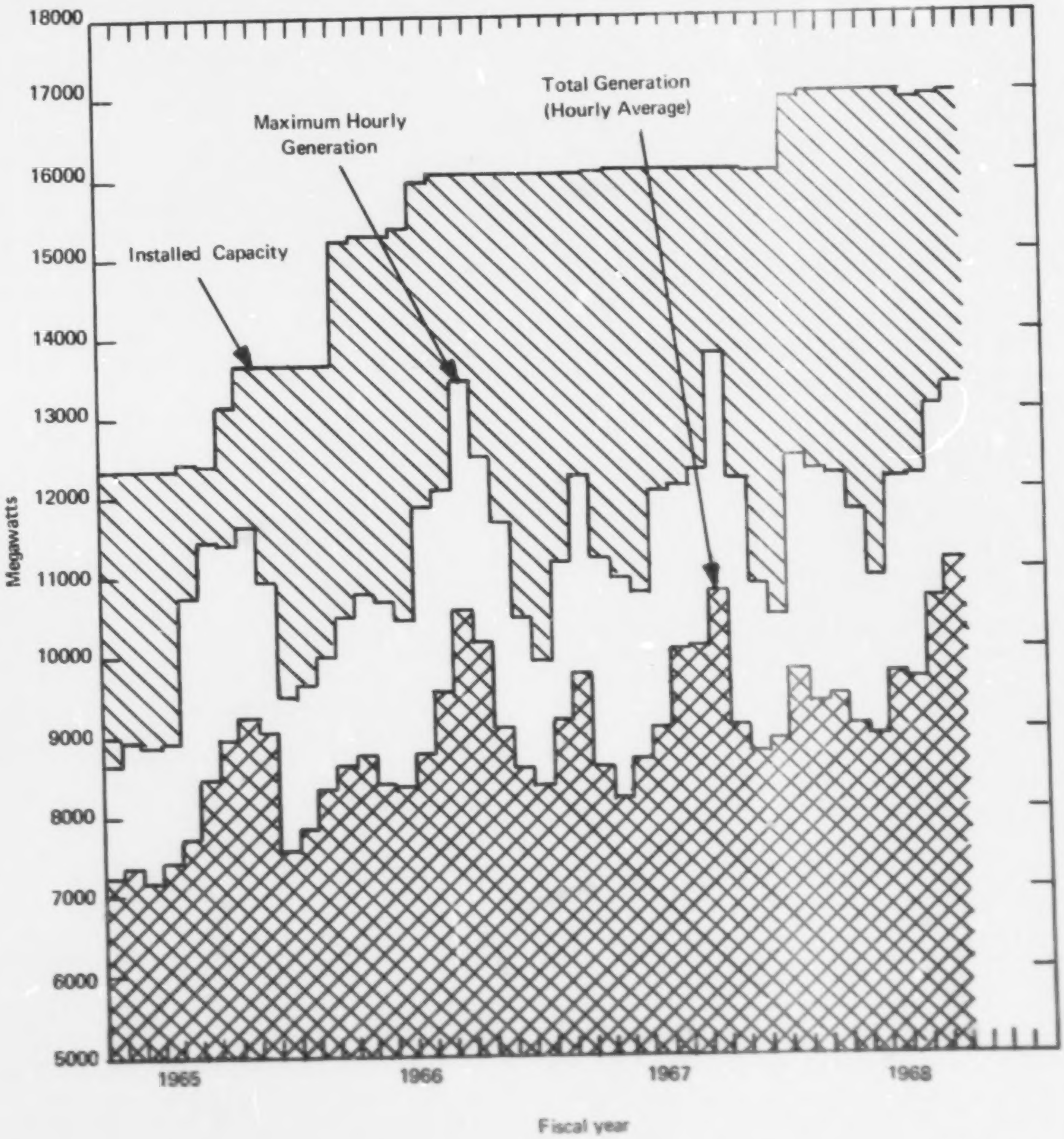


Figure 21. Annual Variation of Load in TVA Power System (84)

less than for equipment which does not have to be any larger for the higher sulfur loading.

There is the possibility that high-sulfur coal could be obtained at lower cost than for the medium-sulfur type—an advantage that has been assumed in some process analyses. This may be true in situations where high-sulfur coal must be beneficiated at extra cost in order to meet a large demand for lower sulfur fuel. However, it is conceivable that very high sulfur coals could actually command a premium if recovery processes were generally adopted as the more desirable method of air pollution control. Also, the advantage of high-sulfur content would be lost rapidly if selective mining were required to obtain it. To minimize cost, the coal deposit should average somewhere near the desired content and the coal should be mined as found and handled at the power plant in such a way as to get a fairly uniform boiler feed—as is usually done in large plants. Moreover, the use of high-sulfur coal (either naturally occurring or rejects from a deep cleaning process for coal) to improve recovery economics probably would be most feasible in a new plant in which the boiler would be designed for the individual coal characteristics.

Product Marketing

The most difficult cost factor to estimate in evaluating recovery processes is the price obtainable for the product. The material is a byproduct, produced not in accordance with the market demand for it but with the demand for electric power, so that the seller is somewhat at the mercy of the buyer. And even a few power plants equipped with recovery facilities would make so much sulfur product that the market would likely be depressed. Finally, if the power company financed and operated the recovery unit a sales agent likely would be needed (or a company sales organization) to sell the product, which would introduce a sales cost difficult to predict.

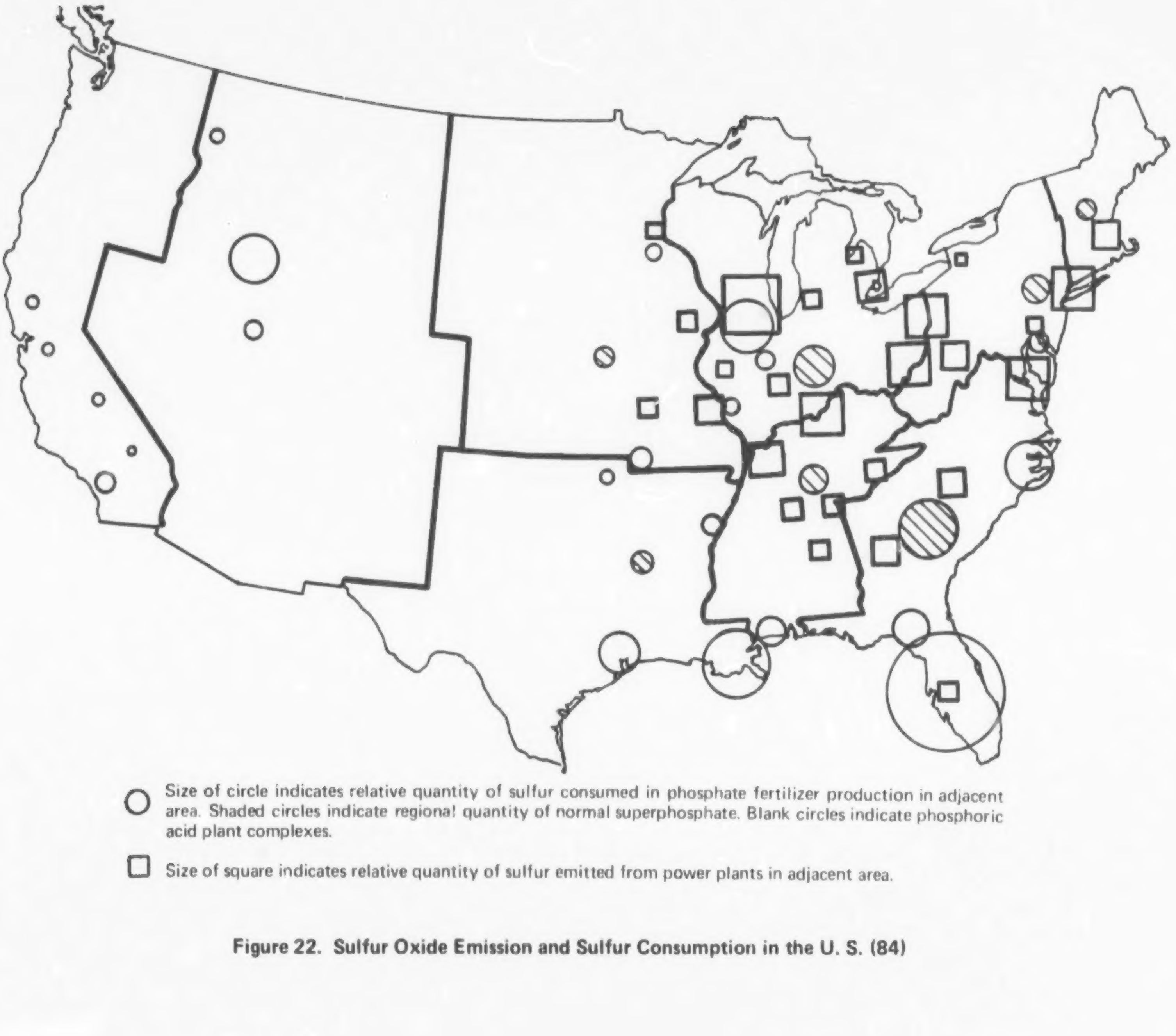
One of the more important considerations is the location of the power plant with respect to the customer for the sulfur byproduct. The very large amount of sulfur involved makes it almost essential to have large-quantity sales to single customers if high sales cost is to be avoided. The sulfur-consuming industry that qualifies best for this is the phosphate fertilizer industry, which accounts for over half the sulfur consumption in the United States. Modern phosphate plants are quite large and afford individual points of high consumption such as needed for marketing power plant byproducts; for example, a plant producing 1000 tons/day of 28-14-0 fertilizer would use 560 tons/day of ammonium sulfate—the output from about 500 mw of power-generating capacity.

To keep shipping costs from reducing the return too much, the phosphate plant should not be very far from the power plant. The relative locations of power plant sulfur emission and phosphate plant sulfur consumption are approximated in figure 22. Unfortunately, much of the phosphate production is in Florida and along the Gulf Coast, where sulfur emission is relatively small. In contrast, a major part of the sulfur emission is in the Northeast where there is little phosphate production. The most favorable area is the Upper Midwest region, where the two are more nearly in balance and much of the recovered sulfur might be used in phosphate plants without shipping very far.

Another possibility is barge shipping of the product from those power plants located on navigable water. Modern barge transport is quite economical; anhydrous ammonia, for example, which requires special refrigeration equipment in transit, is moved on the central rivers for 4-6 mills/ton-mile—indicating that sulfur products could be shipped a thousand miles for less than $4/ton. Fortunately, about 80% of the sulfur dioxide emission is from plants located on navigable rivers.

If fertilizer plants were built near power plants, the product to be shipped would be phosphoric acid, triple superphosphate, ammonium phosphate, or nitric phosphate (made with ammonium sulfate as an intermediate raw material), all products of high enough concentration for economical shipping. At the present time overproduction in the phosphate fertilizer industry makes such ventures unlikely, but presumably this situation will improve in the future. It should also be noted that there has been no great rush to build fertilizer plants near smelter plants, where sulfur recovery is far more economical than in the power industry. There are some examples but not many; however, smelters are not generally located as favorably as power plants in relation to fertilizer plants and to areas of high fertilizer consumption. The most recent sulfur recovery project at a smelter may be significant for the power plant problem; Falconbridge Nickel near Sudbury, Canada, is converting recovered sulfur dioxide to elemental sulfur (by a process developed by Allied Chemical) (4) rather than making the usual sulfuric acid as the end product.

This points again to the upper Midwest as the most favorable location for sulfur oxide recovery. The area is a heavy consumer of fertilizer phosphate (54% of the United States total in 1967) and the high-sulfur coal is there—about 90% of the coal containing over 3.5% sulfur is mined in the block of states comprised by Ohio, Illinois, Indiana, Iowa, western Kentucky, and Missouri. Most of the coal mined in the Eastern States contains less sulfur and therefore recovery economics would not be as good. The nonrecovery limestone processes may be more applicable for this area.



○ Size of circle indicates relative quantity of sulfur consumed in phosphate fertilizer production in adjacent area. Shaded circles indicate regional quantity of normal superphosphate. Blank circles indicate phosphoric acid plant complexes.

☐ Size of square indicates relative quantity of sulfur emitted from power plants in adjacent area.

Figure 22. Sulfur Oxide Emission and Sulfur Consumption in the U. S. (84)

STUDY ASSUMPTIONS AND DESIGN CRITERIA

The conceptual design was developed for a basic scrubbing system plus three process alternatives for using the scrubber effluent.

Process A—Air oxidation to produce ammonium sulfate solution from all of the recovered sulfur and use of the ammonium sulfate solution to produce either crystalline ammonium sulfate or nitric phosphate (28-14-0).

Process B—Addition of sulfuric acid to convert the ammonium sulfite and bisulfite in the scrubber solution to ammonium sulfate and sulfur dioxide. The sulfur dioxide is converted to sulfuric acid for use in the process and the surplus acid is used to produce ammonium phosphate for use in production of a modified nitric phosphate (19-14-0).

Process C—Decomposition of ammonium sulfate by heating to produce ammonium bisulfate and ammonia. The ammonia is recycled to the scrubber and the ammonium bisulfate used to acidulate phosphate rock and produce ammonium phosphate sulfate (20-15-0).

Each process is compared under uniform conditions. In addition, the effects of variables that significantly affect costs are presented.

Plant Size

The size of power plants being built is steadily increasing. Projection of boiler unit size (82) indicates that over 95% of the capacity installed after 1970 will be in units 600 mw or larger and about 80% in units of 1000 mw or higher capacity. By 1980, over half of the total capacity in the United States will be in units 500 mw or larger. Practically all of the remainder will be in small units (200-mw and smaller) 10 yrs old or more and the load factor will be low. Since the pollution problem will thus be centered in the new and larger plants, application of the ammonia scrubbing process to a 500-mw unit was assumed for the base case. To determine the effect of power plant size on economics, estimates were also made for 200- and 1000-mw units.

The efficiency of power plant boilers varies with size and design. Since the amount of coal burned/unit of power produced is important in establishing the quantity of sulfur evolved, the following rates, based on TVA experience, were assumed.

Unit size, mw	Btu/kwh
1,000 new	8,700
1,000 existing	9,000
500 new	9,000
500 existing	9,200
200 existing	9,500

The distinction between new and existing plants is made to reflect improved design of the more modern units.

Sulfur Content of Fuel

The sulfur content of the coal does not significantly influence scrubber design since the size is determined mainly by gas flow rate. However, the size of plants utilizing the scrubber solution is directly affected by the sulfur level in the coal and economy of scale becomes a factor. Moreover, the sulfur content of the fuel determines the tonnage of product that must be sold.

An average sulfur content of 3-4% was assumed and a value of 3.5% was selected for the base case. Large quantities of coal containing more than 4% sulfur are mined, particularly in Illinois, Ohio, Missouri, and western Kentucky (88). Thus, operation with a higher sulfur level, 5%, was also evaluated. To complete the evaluation, the economics of operation with 2% sulfur coal, representing the lower range of sulfur level, was estimated. It was assumed that sulfur content would not influence the price of coal.

Degree of Sulfur Dioxide Removal

The required degree of sulfur dioxide removal is likely to vary depending on geographic location, weather conditions, plant size, and local regulations. Use of ammonia scrubbing will probably be of interest mainly for larger plants that operate near base load conditions and for which a high degree of removal will be necessary. Also, within the limitation of practical scrubber design, a high degree of removal will improve overall economics of the recovery system. A sulfur dioxide removal efficiency of 90% was assumed as the basis for scrubber design.

Dust Removal

A major advantage of wet scrubbing for sulfur dioxide control is ability to remove fly ash from the combustion gases and thereby solve dust emission problems that are of increasing concern to power producers. The present conventional method for control of fly ash in modern plants is through use of electrostatic precipitators which at best are expensive to install and maintain and at worst are unreliable. Many older plants are equipped only with mechanical dust collectors and installation of improved facilities at these is likely to be necessary.

Combustion of coal with 12% ash in a pulverized fuel boiler results in a dust loading of about 4 grains/cubic foot (cu ft) at the boiler exhaust; with a cyclone boiler (a far less common type) the fly ash content would be about one-third this amount. It was assumed that it will be necessary to remove 99.5% of the dust.

For new plants, the scrubbing system will be used to remove fly ash and therefore eliminate the requirement for an electrostatic precipitator. To prevent excessive solids concentration in the ammonium sulfite-bisulfite scrubber liquor, a scrubber stage will be provided ahead of the absorber where dust will be removed by scrubbing with water. Sulfur trioxide and a small portion of the sulfur dioxide in the gas will be absorbed in the first-stage scrubber. Although ammonia will be added to the gas for corrosion control upstream of the scrubber, the liquor in this stage will be acidic and require corrosion-resistant materials of construction in the scrubber and in a clarifier used for separation of the dust. The clarified liquor will be recirculated except for a side stream removed for control of the sulfate concentration.

In existing plants (assumed to be equipped with 90% efficient electrostatic precipitators) continued operation of dust collectors will remove most of the fly ash so that residual amounts can be handled in the absorber.

Operating Time and Capacity Factor

In the design studies of nonrecovery limestone scrubbing processes, the possibility of intermittent operation was recognized. In recovery processes, the heavy investment and market commitments will make it desirable to operate the recovery system whenever the power unit is on-stream to defray the continuing fixed costs. For the base case, a new 500-mw unit, the following schedule was assumed:

Year	Capacity factor, % (nameplate rating)	Annual kwh/ kw capacity
1-10	80	7,000
11-15	57	5,000
16-20	40	3,500
21-35	17	1,500

The same schedule was used for a new 1000-mw plant; for the 200-mw comparison it was assumed that the plant would be 8 yrs old when the recovery unit was installed so that the first 8 yrs in the above schedule would be lost. For comparison of installing ammonia scrubbing facilities in new and existing plants, it was assumed that existing 500- and 1000-mw units would be 3 yrs old.

Plant Location

The major fertilizer markets are located in the Midwest. Because of distribution economics, it is likely that power plants located near the markets will have the most interest in use of the ammonia scrubbing process. Therefore, a midwest location was assumed.

Amount of Storage

The fertilizer market is seasonal because the materials are applied to the soil mainly in the spring and fall of the year. Some storage is provided by sales of intermediates (ammonium sulfate, 28-14-0, 26-19-0, 19-14-0 are in this category) to manufacturers of custom blends; also distributors provide some storage. However, it is common practice for basic producers of fertilizer materials to provide sizable storage facilities to accommodate production during periods of low shipments. Moreover, moving large inventories from storage during relatively short periods requires unusually high investment for materials-handling equipment. The average amount of storage provided with new large fertilizer plants is about 60 days' production, which is normally adequate; if not, the production rate can be reduced or the plant shut down. However, with raw material supplied from a power plant, the fertilizer plant would have to operate to permit continued operation of the pollution control facility. Thus for the present study, storage facilities for 90 days' production were provided.

Stack Gas Reheat

The need for reheat of the cooled gas from the scrubber has been generally accepted but the required level of reheat has not been established. The effect of temperature on plume buoyancy and ground-level concentration of stack gas constituents was studied in detail for the limestone - wet scrubbing conceptual design (83). The results indicated that with a high degree of sulfur dioxide removal (80% or above) the stack temperature is not important. However, to prevent high ground-level concentrations during upset conditions and to avoid increased levels of nitrogen oxides, it was decided that reheat to 250° F should be used as a basis for design. The same basis was used in the present study.

Fertilizer Technology

The technology involved in production of fertilizer from ammonium sulfate by processes A and B was assumed to be commercially proven and therefore evaluation was not necessary in this study. Information for capital and operating cost estimates was obtained from quotations on battery limits plants and from TVA experience.

In process C, neither the decomposition of ammonium sulfate to ammonium bisulfate nor the extraction of phosphate rock with ammonium bisulfate has been carried out in commerical or pilot equipment. The process and equipment design was based on results of limited, exploratory, small-scale work by TVA and therefore should be considered as a preliminary study only. Estimates for this process may be in error by as much as 50%.

Solids Disposal

Fly ash removed in the clarifier will be sluiced to an ash pond for storage, no additional expense beyond normal disposal costs should be incurred. It was assumed that the normally basic ash would neutralize the acidity resulting from sulfur oxides absorbed in the dust scrubber. If not, pH control of the sluice pond overflow might be necessary.

It was assumed that calcium sulfate from the fertilizer plants would be stored in a pond as is common in the fertilizer industry. Water pollution control facilities were provided. Storage for 10 yrs' production of gypsum was assumed.

Process Indices

A summary of indices for the various processes and operating levels is given below. Flowsheets for each process are shown in Appendix C and are designated as follows:

Process A - A69-A-5
Y69-A-6
Process B - A69-A-11
Y69-A-12
Process C - A70-A-3
A70-A-4

General:

Power plant size, mw	Type plant	Sulfur content of coal, %	Gas flow at boiler exit, acfm	Product rate, ton/hr Process A (28-14-0)	Process B (26-19-0)	Process C (19-14-0)
200	Existing	3.5	648 M	18.4	13.9	8.1
500	New	2.0	1,620 M	24.8	18.8	10.9
500	New	3.5	1,620 M	43.4	32.9	19.1
500	Existing	3.5	1,620 M	44.4	33.7	19.6
500	New	5.0	1,620 M	62.0	46.9	27.3
1,000	New	3.5	3,240 M	83.9	63.4	37.1
1,000	Existing	3.5	3,240 M	86.8	65.7	38.3

Operating Indices for Process A (28-14-0 Production):

Ammonia Scrubbing

Scrubber effluent		
Flow rate, lb/hr	72.8	M
Temperature, °F	120	
Salt concentration, % by wt $(NH_4)_2SO_4$	50	
NH_3:S mole ratio	1.49	
Neutralizer effluent		
Flow rate, lb/hr	98.4	M
Temperature, °F	188	
Salt concentration, % by wt $(NH_4)_2SO_4$	40	
NH_3:S mole ratio	2.0	
Oxidizer effluent		
Flow rate, lb/hr	102	M
Temperature, °F	135	
Pressure, psig	100	
pH	6.5	
Retention time, hr	1	

Nitric Phosphate Production

Extractor raw material rates, lb/hr		
Nitric acid	77.9	M
Phosphate rock	41.3	M
Antifoam	16.5	
Precipitator effluent		
Flow rate, lb/hr	219	M
Temperature, °F	150	
Filter effluent		
Flow rate, lb/hr	195	M
Temperature, °F	100	
Gypsum slurry		
Flow rate to pond, lb/hr	315	M
Neutralizer		
Ammonia flow rate, lb/hr	5650	
Effluent temperature, °F	150	
Evaporator		
Effluent flow rate, lb/hr	107	M
Steam requirement, lb/hr	175	M
Salt concentration, % by wt 28-14-0	99.7	
Prilling tower		
Recycle ratio, lb recycle/lb product	1:4	
Conditioner rate, lb/lb product	0.02	
Product rate, lb/hr	86.8	M

Operating Indices for Process B (26-19-0 Production):

Ammonia Scrubbing

Scrubber effluent		
Flow rate, lb/hr	67.8	M
Temperature, °F	120	
Salt concentration, % by wt $(NH_4)_2SO_4$	52.5	
NH_3:S mole ratio	1.32	
Stripper solution to precipitator		
Flow rate, lb/hr	68.7	M
Temperature, °F	114	

NH_3 :S mole ratio	2.0	
Nitric Phosphate Production		
Extractor raw material rates, lb/hr		
Nitric acid	51.5	M
Phosphate rock	40.5	M
Antifoam	16.2	
Sulfuric acid	11.4	M
Precipitator effluent		
Flow rate, lb/hr	170	M
Temperature, °F	150	
Filter effluent		
Flow rate, lb/hr	146	M
Temperature, °F	100	
Gypsum slurry		
Flow rate to pond, lb/hr	310	M
Neutralizer		
Ammonia flow rate, lb/hr	5200	
Effluent temperature, °F	150	
Evaporator		
Effluent flow rate, lb/hr	81.3	M
Steam requirement, lb/hr	129	M
Salt concentration, % by wt 26-19-0	99.7	
Prilling tower		
Recycle ratio, lb recycle/lb product	1:4	
Conditioner rate, lb/lb product	0.02	
Product rate, lb/hr	65.7	M

Operating Indices for Process C (19-14-0 Production):

Ammonia Scrubbing		
Scrubber effluent		
Flow rate, lb/hr	72.8	M
Temperature, °F	120	
Salt concentration, % by wt $(NH_4)_2SO_4$	50	
NH_3 :S mole ratio	1.49	
Neutralizer effluent		
Flow rate, lb/hr	98.2	M
Temperature, °F	163	
Salt concentration, % by wt $(NH_4)_2SO_4$	40	
NH_3 :S mole ratio	2.0	
Oxidizer effluent		
Flow rate, lb/hr	102	M
Temperature, °F	185	
Pressure, psig	100	
pH	6.5	
Retention time, hr	1.0	
Nitric Phosphate Production		
Net heat from boiler, Btu/hr	115	MM
Evaporator-crystallizers		
$(NH_4)_2SO_4$ rate to decomposer, lb/hr	45.2	M
$(NH_4)_2SO_4$ temperature to decomposer, °F	130	
Decomposer effluent		
Flow rate, lb/hr	37.8	M
Temperature, °F	700	
$(NH_4)_2S_2O_7$:$(NH_4)_2SO_4$ mole ratio	1.67	
Extractor-precipitators		
Solubilizing tank effluent		
Flow rate, lb/hr	53.5	M
Temperature, °F	220	
Phosphate rock flow rate, lb/hr	17.2	M
Effluent rate to filter, lb/hr	110	M
Filter effluent		
Flow rate, lb/hr	77.5	M
Temperature, °F	115	
Gypsum slurry		
Flow rate to pond, lb/hr	135	M
Preneutralizer raw material rates, lb/hr		
Effluent from scrubbers	79.8	M
Ammonia	1660	
Ammoniator-granulator		
Throughput rate, lb/hr	509	M
Discharge		
Moisture content, % by wt H_2O	4.0	
Temperature, °F	180	
Dryer		
Throughput rate, lb/hr	492	M
Discharge		
Moisture content, % by wt H_2O	1.5	
Temperature, °F	190	
Recycle ratio to ammoniator-granulator, lb recycle/lb product	12:1	
Conditioner rate, lb/lb product	0.02	
Product rate, lb/hr	38.3	M

EQUIPMENT SELECTION AND DESCRIPTION

As discussed earlier, use of ammonia scrubbing for recovery of sulfur dioxide has been studied over a long period. Results of these studies are not directly applicable to the current design, mainly because of difference in scale, but some of the findings are useful in selection of equipment type and design of required facilities.

Selected Reported Technology

Packed Absorbers—Most of the pilot and full-scale work with ammonia scrubbing has been done in packed absorbers. At Cominco, off-gas from sintering machines in a smelting operation was treated with ammonia to remove sulfur dioxide. Approximately 300,000 cfm of gas containing about 0.75% sulfur dioxide was handled in two parallel systems (half the flow in each) comprised of a lead cooling tower about 25 feet square (ft sq) and 48 ft high followed by three lead-lined absorption towers packed with wood grids also 25 ft sq and 32 ft high. Liquid flow was cocurrent with the gas in the first absorber, countercurrent in the second, and cocurrent in the third. Circulation rate was 1200-1500 gal/min in the first and second units and 600-800 gal/min in the third; aqua ammonia was added to the circulating streams. The solution temperature was controlled at about 90° F by water cooling in shell and tube exchangers (aluminum tubes and steel shell). Solution was bled forward from the last tower to the first where the product concentration was about 240 g/l of sulfur, mainly ammonium bisulfite. The tail gas contained about 0.1% sulfur dioxide; absorption efficiency was approximately 85%. Pressure drop in the system was about 10 in of water. Most of the dust was removed ahead of the absorbers; the method was not discussed.

The lead used in tower lining and aluminum for exchanger tubing were satisfactory materials of construction (25). In other portions of the Cominco plant, type 316 stainless steel pumps were used for ammonium sulfate solution, lead-lined tanks for storage of weak sulfuric acid (70%) and ammonium sulfate solution, mild steel tanks for storage of concentrated sulfuric acid (93%), and neoprene-lined steel evaporators and crystallizers for ammonium sulfate solution.

At TVA (41), a pilot plant was operated to study scrubbing of combustion gases with ammonium sulfite-bisulfite solution. A schematic flow diagram of the pilot plant equipment is shown in figure 23. Pulverized coal was burned at a rate of 150-200 lb/hr in a fire tube boiler and the combustion products were passed through a mechanical dust collector and cooled by humidification to produce gas for the pilot plant. Gas containing about 0.3%

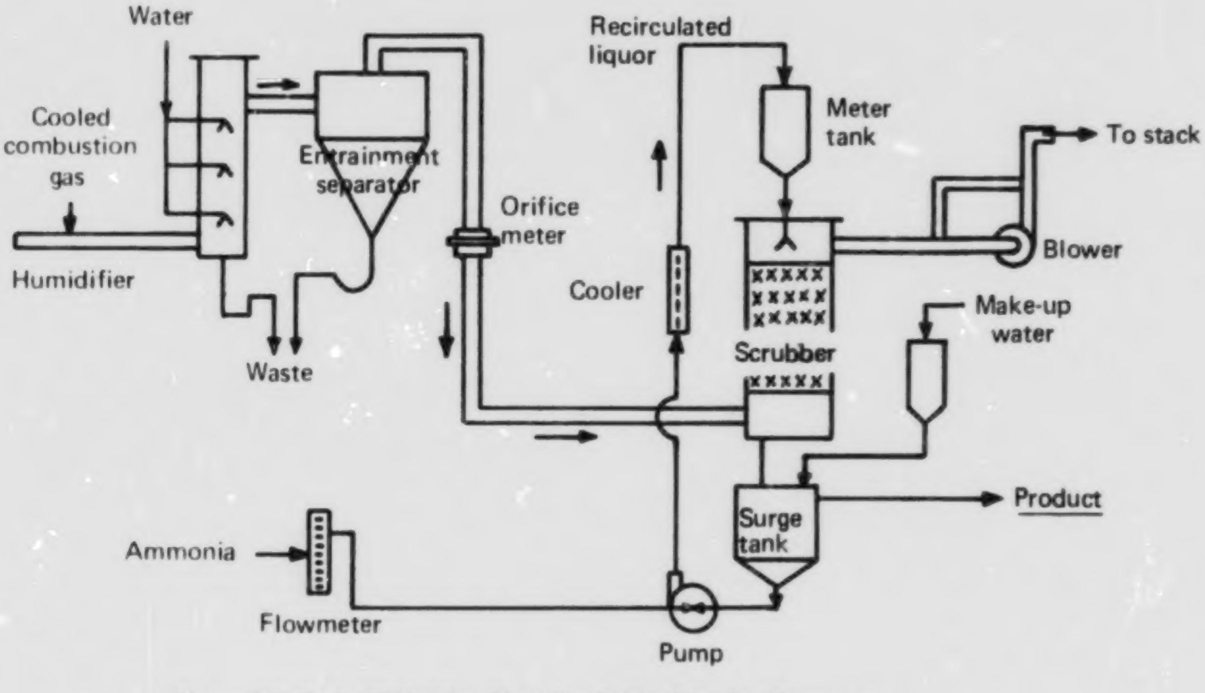


Figure 23. Early TVA Pilot Plant for Sulfur Dioxide Recovery by Ammonia Scrubbing (41)

sulfur dioxide entered the bottom of the scrubber, a mild steel tower 2 ft in diameter by 10 ft high packed with 2-in ceramic rings to a depth varied from 3-8 ft. Scrubber solution was recirculated to the tower and heat was removed in a water-cooled exchanger. Gaseous ammonia was added to the solution in the recirculation system. The major variables studied were circulation rate, pH and concentration of solution, depth of packing, and gas velocity. The conditions of operation for the various tests are shown in table 7 and effect of recirculation rate and packing depth on recovery of sulfur dioxide in figure 24.

The liquor rate required to obtain a given recovery increased as the depth of packing decreased. The approximate rates required for 80% recovery with a pH of 6.4 are given below together with the calculated absorption coefficients.

Packing depth, ft	Liquor rate Gal/min	Liquor rate Gal/(min) (sq ft)	Overall coefficient Lb mole/(hr) (cu ft) (atm)
8	4	1.3	5.8
4	5	1.6	11.5
3	7	2.2	15.3

Table 7. Averaged Operating Conditions for Pilot Plant Runs (41)

	Scrubbing liquor					Stack gas to scrubber					
Principal variable	Rate to tower, gal/min	pH	Temp., °F In	Temp., °F Out	NH_3 concn., moles/ 100 moles H_2O	Volume,[a] cu ft/min	Temp., °F Dry bulb	Temp., °F Wet bulb	SO_2 concn., %	SO_2 recovered, %[b]	Depth of packing, ft
Scrubbing liquor rate	0.5-9	6.3	123	127	20	330	129	124	0.29	56-80	8
Scrubbing liquor pH	5	5.6-6.8	123	124	20	340	122	121	0.30	0-90	8
Depth of packing	0.5-9	6.4	121	123	20	350	121	123	0.30	35-84	3-8
Gas velocity	5	6.4	122	124	20	250-600	124	122	0.28	84-85	5
Liquor concentration	5	6.4	123	127	10-45	320	125	122	0.29	68-85	5
Material balance	5	6.4	120	124	20	350	121	121	0.27	82	5
Ammonia recovery	5	4.6-5.8	110	115	–	350	124	121	–	–	5

[a] At scrubber temperature and 725 mm pressure.
[b] As percent of SO_2 in the stack gas to scrubber.

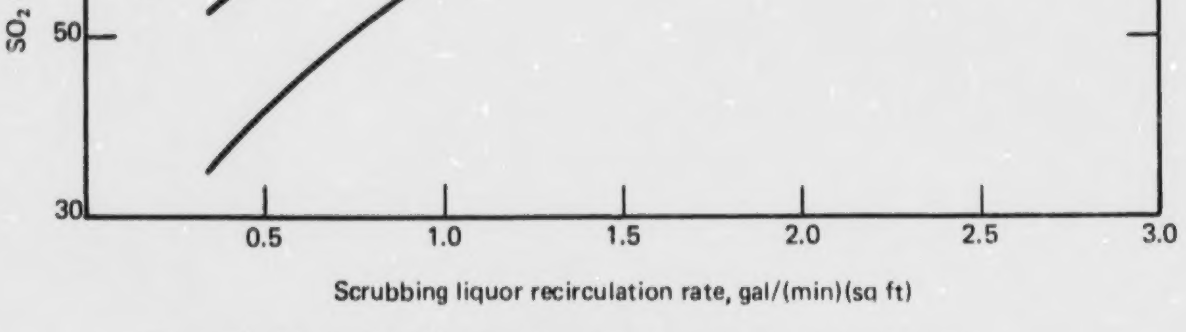


Figure 24. Effect of Packing Depth on SO_2 Recovery at Various Liquor Recirculation Rates (at pH 6.4) (41)

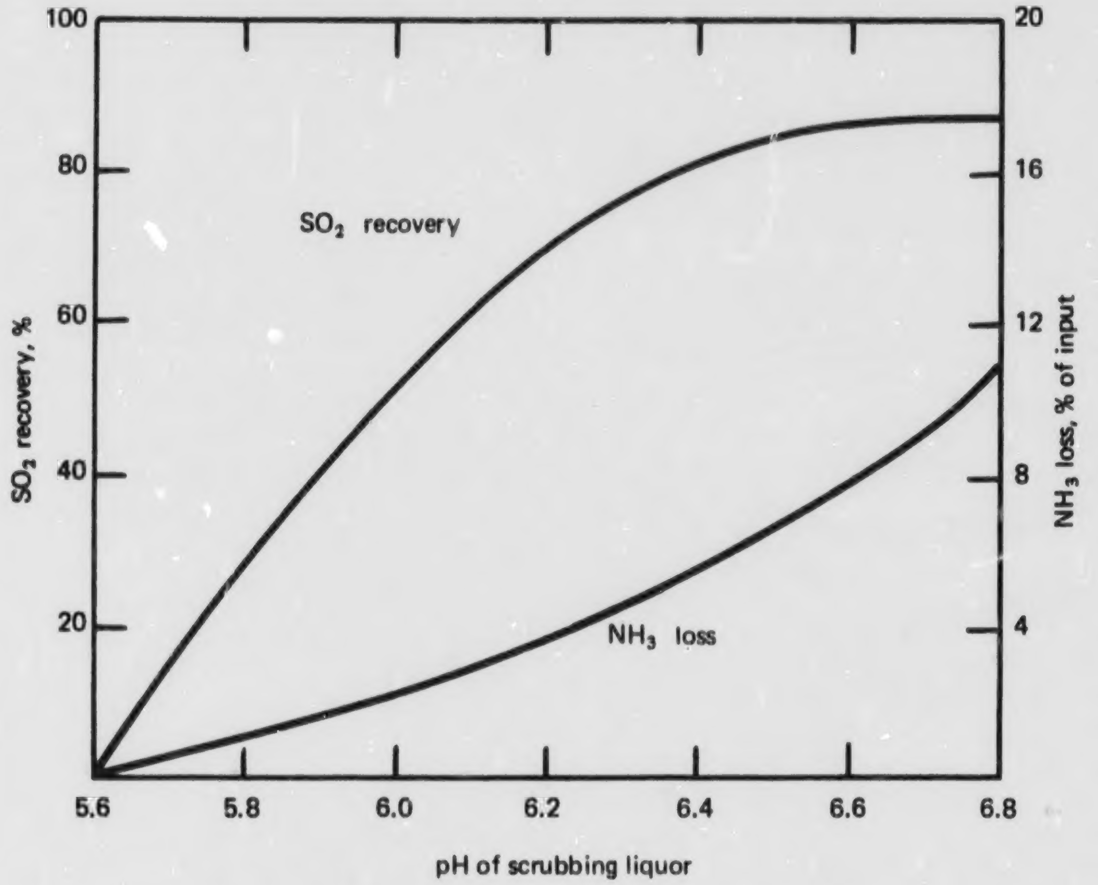


Figure 25. Effect of pH of Scrubbing Liquor on SO_2 Recovery and NH_3 Loss (41)

The effect of scrubbing liquor pH on sulfur dioxide recovery and ammonia loss is shown in figure 25 and the effect on composition of the scrubber solution in table 8. These data show that the mole ratio of sulfite to bisulfite increased with pH and that the amount of ammonia required for recovery of sulfur dioxide increased as the pH increased.

Change in gas velocity over the range studied, 1.4-3.5 ft/sec, did not significantly change the degree of sulfur dioxide recovery; pressure drop through the scrubber was less than 1 in of water.

Data on effect of solution concentration at a pH of 6.4 on sulfur dioxide recovery and ammonia loss are summarized below.

Scrubbing liquor							
			Composition, g/l				
				S			
Moles NH_3/100 moles H_2O	Specific gravity	H_2O, % by wt	NH_3	Total	As $SO_4^=$	SO_2 recovery, % of SO_2 in stack gas	NH_3 loss, %[a]
10.5	1.15	70	81	98	13	85	5.4
23.0	1.25	52	143	175	13	81	8.4
36.0	1.32	40	181	238	21	72	17.5
44.5	1.33	35	200	255	20	68	23.5

[a] Based on ammonia added to maintain steady state.

Table 8. Effect of pH on Composition of the Scrubber Effluent (41)

			Effluent composition, g/l					S:NH_3 mole ratio based on		% of S recoverable as	
				S							
Solution pH	Specific gravity	SO_2 recovered, %	NH_3	Total	As $SO_4^{=}$	Degree of oxidation,[a] %	Ammonium sulfite: bisulfite mole ratio[b]	Total S and total NH_3	NH_3 and S combined as ammonium sulfite and bisulfite	$(NH_4)_2SO_4$	H_2SO_4
5.6	1.18	0	84.3	125	20.4	16.3	0.15	0.790	0.890	–	–
5.9	1.19	47	95.0	133	23.3	17.5	0.26	0.735	0.825	67	33
6.1	1.20	58	104.5	139	24.7	17.8	0.39	0.705	0.775	69	31
6.4	1.24	82	131.5	169	20.7	12.3	0.67	0.655	0.720	70	30
6.6	1.25	85	149.5	177	21.6	12.2	1.14	0.630	0.655	79	21
6.8	1.25	90	155.5	179	20.8	11.6	1.42	0.605	0.628	82	18

[a] $\left(\frac{SO_4^{=}S}{\text{Total S}} \times 100\right)$.

[b] Calculated from analyses for total S, NH_3, and $SO_4^{=}$.

Tests were made to simulate a second-stage scrubbing operation for ammonia recovery. With a sulfur dioxide concentration of 0.05% (gas composition from first stage) and circulation of dilute ammonium sulfite-bisulfite solution at a rate of 1.6 gal/min/sq ft, ammonia loss was reduced to about 0.3%.

Simon-Carves Limited of England also developed an ammonia scrubbing process and constructed a large pilot plant (56,000 cfm) at the North Wilford Power Station at Nottingham. The gases were scrubbed in countercurrent flow with a solution of ammonium sulfite-bisulfite. A single-stage scrubber–160-sq-ft cross section, constructed from mild steel and coated with Epicote resin–was packed with 5 ft of wood grids 3/32 in thick on 3/4-in sq pitch. Liquor was circulated at a rate of 1600 gal/min using Ni-Resist pumps and rubber-lined mild steel pipe. Pressure drop was approximately 1 in of water. About 95% of the sulfur dioxide in the inlet gas (0.13%) was removed in the scrubber. Ammonia loss in the single-stage unit was high. A typical composition of liquor produced was:

	Mole/l
$(NH_4)_2SO_4$	1.3
$(NH_4)_2S_2O_3$	0.95
$(NH_4)_2SO_3$	0.75
NH_4HSO_3	0.5

Andrianov and Chertkov (3) described an experimental industrial application of ammonia scrubbing in Russia. The off-gas [100,000 Nm³/hr or 55,000 scfm (standard cubic feet per minute)] from a 160- to 200-ton/hr boiler was scrubbed with an aqueous solution of ammonium sulfite (after the dust had been removed in an electrostatic precipitator and the gas cooled to 30-35° C). The resulting solution of ammonium bisulfite was thermally decomposed to produce sulfur dioxide and the solution was recycled.

A five-stage, lead-lined mild steel tower was used as a cooler and absorber. The lower section was lined with acidproof brick and packed with 50- by 50 mm ceramic rings; in this section, the inlet gas was cooled from 160-30° C. The next three sections, the absorber, and the top ammonium recovery section were also packed with ceramic rings. The sections were separated by horizontal, lead-covered trays which permitted flow of gas but collected the liquor from each stage separately. Liquid distributors were made of aluminum except in the gas-cooling section where rubber-coated steel was used. Stainless steel pumps and aluminum pipe with stainless fittings were used for handling the scrubber solution. Water recirculated to the gas-cooling stage was handled in rubber-lined pumps and pipes.

Residual dust in the gas caused plugging problems throughout the system and it was necessary to install filters to reduce the ash content of the scrubber solutions to 1-2 g/l. Cooling of effluent from the gas-cooling stage was also a problem. Cooling the gas, which normally contained about 0.3% sulfur dioxide and 2.5 g/Nm³ of ash, from 170 to 30° C was attained with a water flow rate of 170-300 m³/hr. The cooling process was accompanied by absorption of sulfur dioxide from the flue gas; on the average about 10% of the sulfur dioxide was absorbed in the cooling water, giving a sulfurous acid and salt concentration of 0.5 g/l. At a liquid flow rate of 300 m³/hr, only 85% of the fly ash was removed; increasing the rate to 460 m³/hr increased the dust removal to 91%. Modification of the liquid distributor gave 92-94% removal of the ash with a liquid flow rate of 250-280 m³/hr. The acidic water reacted with fly ash to form ferrous and aluminum salts so that only about 20% of the absorbed sulfur dioxide was free acid. However, the solution was acidic enough to cause corrosion problems.

Removal of 90% of the sulfur dioxide was achieved by controlling the S/C mole ratio in the final scrubbing stage at 0.76-0.78. The solution from the first stage had an S/C mole ratio of 0.95, indicating that about 90% of the sulfur dioxide was in the bisulfite form. The absorption coefficient averaged about 0.04 kg/m^2/hr/mm Hg. Packing volume in the three absorption stages totaled 300 m^3 or about 30,000 m^2.

Ammonia loss was slight, 7-8 kg/hr, mainly due to carry-over from the top-stage entrainment separator.

Small-scale studies of ammonia scrubbing in packed towers were made by Chertkov and Johnstone. Also, packed absorbers are being used in the full-scale units being operated in France and in Czechoslovakia. Design and operating information on these units is not available except that a spiral packing is used in the Czechoslovakian absorber with gas rates up to 12 ft/sec.

Venturi Scrubber—Absorption of sulfur dioxide by ammonium sulfite-bisulfite solution in a venturi scrubber was studied in small-scale equipment by Volgin *et al* (91). Apparently, dust-free simulated gas was used. The scrubber throat was either rectangular with a 10- by 15-mm cross section and a length of 13-mm or round with a 20-mm diameter and a length of 10 mm.

In experiments carried out at a constant gas velocity of 30 m/sec in the throat and a solution with S/C mole ratio of about 0.81, absorption remained relatively constant for low concentrations of sulfur dioxide in the inlet gas (0.14-0.6). At higher concentrations, beyond the levels encountered in power plant stack gas, the absorption efficiency decreased sharply.

The effect of hydraulic conditions on degree of absorption is shown in figure 26. The inlet gas concentration was not stated. The percent absorption as a function of hydraulic conditions was expressed as:

$$\%\ \text{absorption} = 8.54\, w^{0.42}\, q^{0.27} \qquad (44)$$

where, w = gas flow rate, m/sec
q = liquid flow, l/m^3

Pressure drop was related to hydraulic conditions as shown in figure 27. During the tests to generate these data, the concentration of sulfur dioxide in the gas was 0.34% and S/C in solution was 0.83.

The high gas velocity in the throat and high absorbent flow rates required for a high degree of sulfur dioxide removal make a single-stage venturi scrubber economically unsuitable in comparison with packed- and bubble-type apparatus. The very short time of contact between gas and liquid (0.004 sec at 25 m/sec) is not enough for the diffusion and liquid circulation necessary to move the gas molecules into the interior of the drops. The gas accumulates on the surface of the drops so that the external portion of the drop, the area that "sees" the gas, has a higher concentration of sulfur dioxide than the bulk of the liquid. The driving force for absorption is therefore reduced. When the drops are collected, the concentration of sulfur dioxide in the liquid is lower than it was on the surface of the drops. If this liquid is reintroduced into the scrubber, the sulfur dioxide vapor pressure will be lower above the new drop than it was at the final moment in the preceding pass. The advisability of carrying out the absorption in several stages is evident. Moreover, a series arrangement of several scrubbers makes possible counterflow of gas and liquid which increases the degree of absorption.

The results of test by Volgin *et al* (91) on absorption in a multistage apparatus are shown in figure 28. The gas velocity was 30 m/sec, sulfur dioxide concentration was 1.1%, and S/C was 0.82.

Volgin's work indicates that multistage absorption in venturi scrubbers is competitive with packed- and bubble-type absorbers. The author cautioned, however, that the data should be considered preliminary because of the small scale of the apparatus.

Wetted Wall Absorber—Small-scale studies of sulfur dioxide absorption in ammonium sulfite-bisulfite solutions in a wetted-wall absorber were reported by Chertkov (11). The primary objective of the work was to establish the effect of initial gas-phase sulfur dioxide concentration on mass transfer coefficients. A wetted-wall apparatus was chosen for the work because the contact phases remain constant and the flow rates can be controlled so that absorption of sulfur dioxide causes a negligible change in solution composition.

The gas mixture was prepared by adding sulfur dioxide to air and was introduced at the bottom of an absorption tube 1.2 centimeters (cm) in diameter and 106 cm high (active surface of 400 sq cm). The absorbing solution was fed through a liquid seal, passed through the orifice of a conical nozzle, and flowed over the edge of the absorption tube. Thus the flow was countercurrent.

The results of tests with sulfur dioxide concentrations in the inlet gas varying from 0.08-2.0% are shown in figure 29. The tests were carried out at a gas rate of 7 l/min (velocity, 1 m/sec), a solution flow rate of 75 ml/min [2 l/(min)(linear m) of tube perimeter], and a temperature of 21-25° C. The composition of the absorbing solution was:

Total NH_3, moles/l	7.8-8.2
Effective NH_3 (as sulfite and bisulfite), moles/l	4.6-4.7
SO_2 (as sulfite and bisulfite), moles/l	3.70-3.75

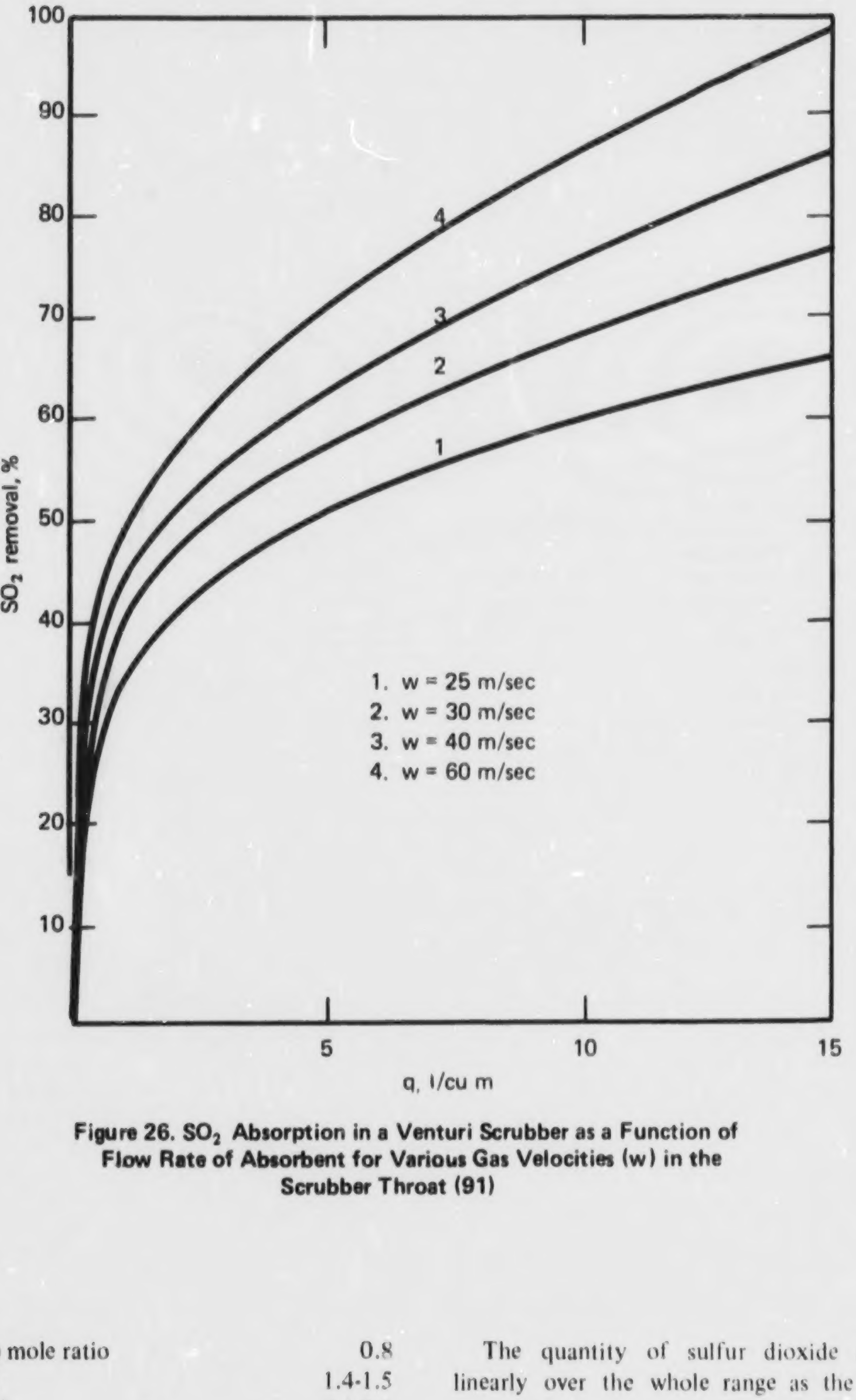


Figure 26. SO_2 Absorption in a Venturi Scrubber as a Function of Flow Rate of Absorbent for Various Gas Velocities (w) in the Scrubber Throat (91)

SO_2:NH_3 (effective) mole ratio	0.8
$(NH_4)_2SO_4$, moles/l	1.4-1.5
$(NH_4)_2S_2O_3$, moles/l	0.1-0.2
Solution density, kg/l	1.26-1.28

The equilibrium sulfur dioxide pressure over a solution of this composition was 0.19-0.23 mm mercury, which corresponds to a sulfur dioxide concentration in the gas phase of 0.025-0.03% by volume.

The quantity of sulfur dioxide absorbed increased linearly over the whole range as the sulfur dioxide gas concentration increased. This indicates that the chemical reactions between sulfur dioxide and the liquid phase do not limit the overall sulfur dioxide solution process and that the mass transfer coefficient does not depend on the sulfur dioxide concentration in the gas phase. The experimental values of mass transfer also confirm this since, except at very low sulfur dioxide gas concentration approaching the equilibrium sulfur dioxide pressure over the solution, the value for the coefficient was nearly constant at about 10 moles/hr/m^2.

Sieve Plate Absorber—The absorption of sulfur dioxide from flue gas was studied by Chertkov and coworkers in a laboratory absorber containing six perforated plates (7). With a gas velocity of 1.5-2.4 m/sec, a total pressure drop of 150-200 mm of water, and a temperatue of 30-33° C, 90% sulfur dioxide removal was achieved under foaming conditions. Foaming on the plates was found to depend on the ratio of gas velocity through the perforations to the velocity through the scrubber column; narrow limits of the ratio, between 5 and 6, were found necessary. The absorption coefficient increased directly with resistance of the solution layer on the plates.

A pilot plant designed to handle 10,000 m^3/hr (5500 scfm) of flue gas was operated at a Moscow power plant to study absorption of sulfur dioxide in ammonium sulfite-bisulfite solution (12). The plant, shown in figure 30, was comprised of a six-stage perforated-plate absorber constructed of aluminum with appropriate liquid and gas-handling equipment. The tower was operated under foaming conditions to produce a solution containing 9-10 moles ammonia/100 moles water and an S/C ratio of about 0.9. Approximately 90% sulfur dioxide removal was achieved from inlet gas containing 0.3-0.4% sulfur dioxide. Most of the fly ash in the inlet gas (concentration was not given) was removed in the lower stages of the scrubber. Pressure drop at a gas velocity of 1.5-2 m/sec in the total cross section was 30-35 mm of water across one plate and 200-220 over the whole column.

The scrubber solution was not collected for recirculation at each stage but flowed countercurrently to the gas from plate to plate. The effect of inlet solution composition on absorption coefficient is shown in table 9.

Operating conditions considered to be optimum were:

Linear gas rate, m/sec	
In the total cross section	1.70
In perforations of grates	10.0
Scrubber hydraulic resistance, mm H_2O	186
Circulation of solution, m^3/m^2-hr	2.60
Average solution temperature in gratings, °C	32.0
Ratio of SO_2:NH_3eff. in solution	
Entry	0.809
Exit	0.900
SO_2 content in flue gas, % total	
Entry	0.358
Exit	0.041
Degree of SO_2 recovery, %	88.5

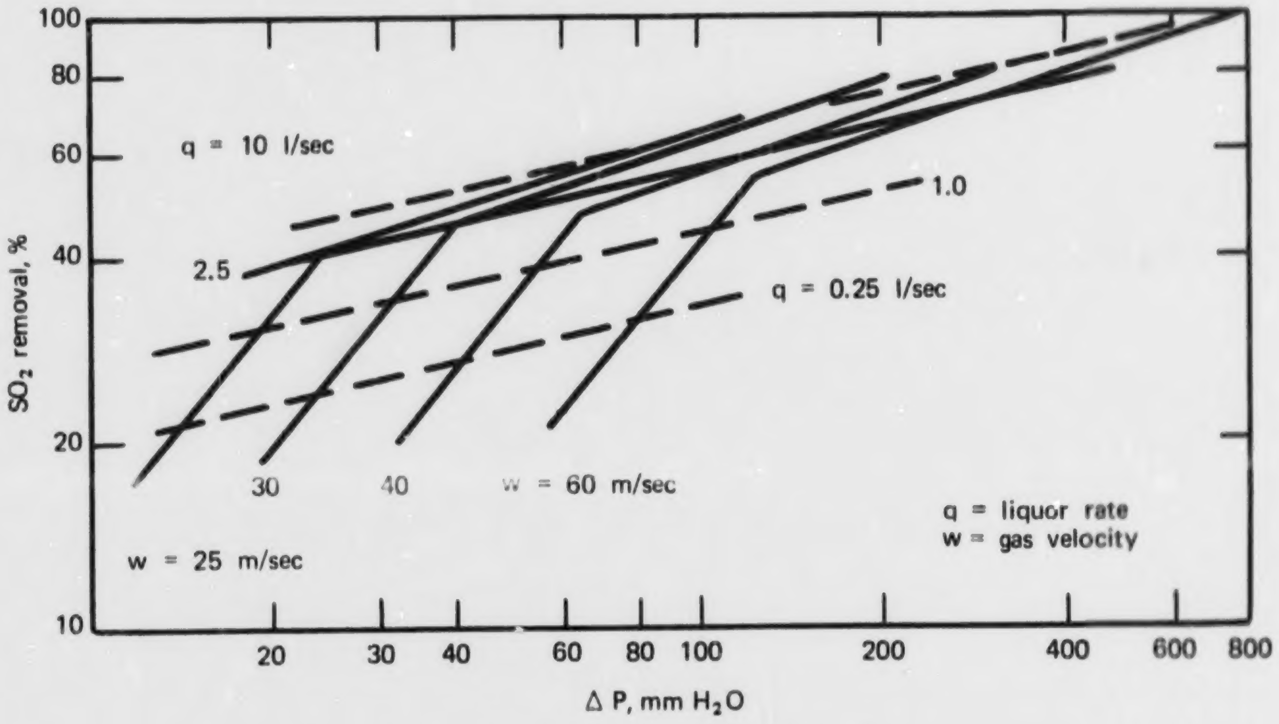


Figure 27. SO_2 Absorption as a Function of Pressure Drop in Scrubber (91)

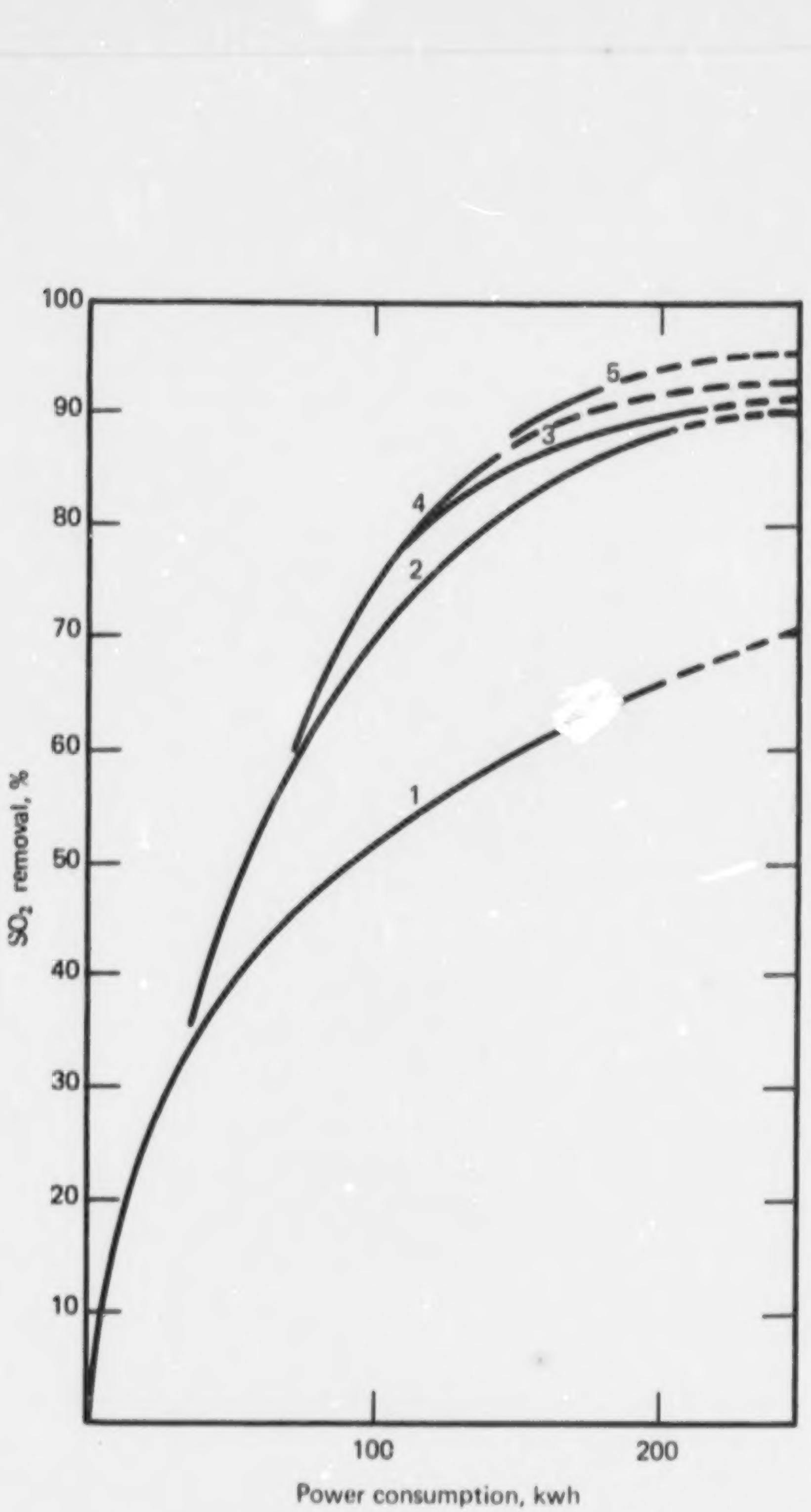


Figure 28. SO_2 Absorption as a Function of Total Consumption of Electric Power in a Multistage Venturi Arrangement (the curve number corresponds to the number of stages; pump pressure: 40 mm H_2O) (91)

Average coefficient of absorption	
K^{I}: $\dfrac{\text{moles } SO_2}{m^2\text{-hr-\% } SO_2}$	1780
K^{II}: $\dfrac{\text{kg } SO_2}{m^3\text{-hr-mm Hg}}$	21.2

Major Alternatives

The equipment required for the ammonia scrubbing process can be divided into three major categories:

1. Gas scrubbing and reheat
2. Conversion of the scrubber solution to ammonium sulfate
3. Use of ammonium sulfate in production of fertilizer

Several alternatives were considered in selection of equipment type for category 1. For the other categories the specific process selected dictated choice of equipment.

Gas Scrubbing—A study of scrubber types was made on the basis of information from plant visits, scrubber consultants, scrubbers vendors, and literature sources.

A scrubber for use in an ammonia scrubbing process should have the following characteristics:

1. Minimum pressure drop (12 in of water or less at 90% SO_2 absorption).
2. High efficiency for removal of sulfur dioxide (at least 90%) and particulates (minimum, 99.5%).
3. Minimum oxidation of sulfite to sulfate (important for process B only).
4. Resistance to plugging by solids removed from the gas stream.
5. A high turndown ratio (ratio of design volume rate to minimum volume rate).
6. Provision for stagewise contact of gas and liquid and for maintaining separate circulation of liquid streams in each stage. This is considered to be the most important single requirement as it is necessary in order to get good sulfur dioxide absorption with minimum ammonia loss.

The following types of scrubbers were considered:

1. Packed
   a. Countercurrent flow
   b. Cocurrent flow
   c. Crossflow
2. Sieve tray
   a. Countercurrent with and without downcomers
   b. Crossflow impingement plate with downcomers
3. Venturi
4. Spray
   a. Cyclonic
   b. Spray tower
5. Mobile-bed
6. Orifice

With no dust collection ahead of the scrubber (new power plants), the dust loading will be about 7-9 grains/cu ft. If a dust collector is used upstream of the scrubber (existing power plants), the inlet dust loading is reduced to about 1 grain/cu ft or less. Most scrubber designs will effectively remove particles 10 microns in diameter or

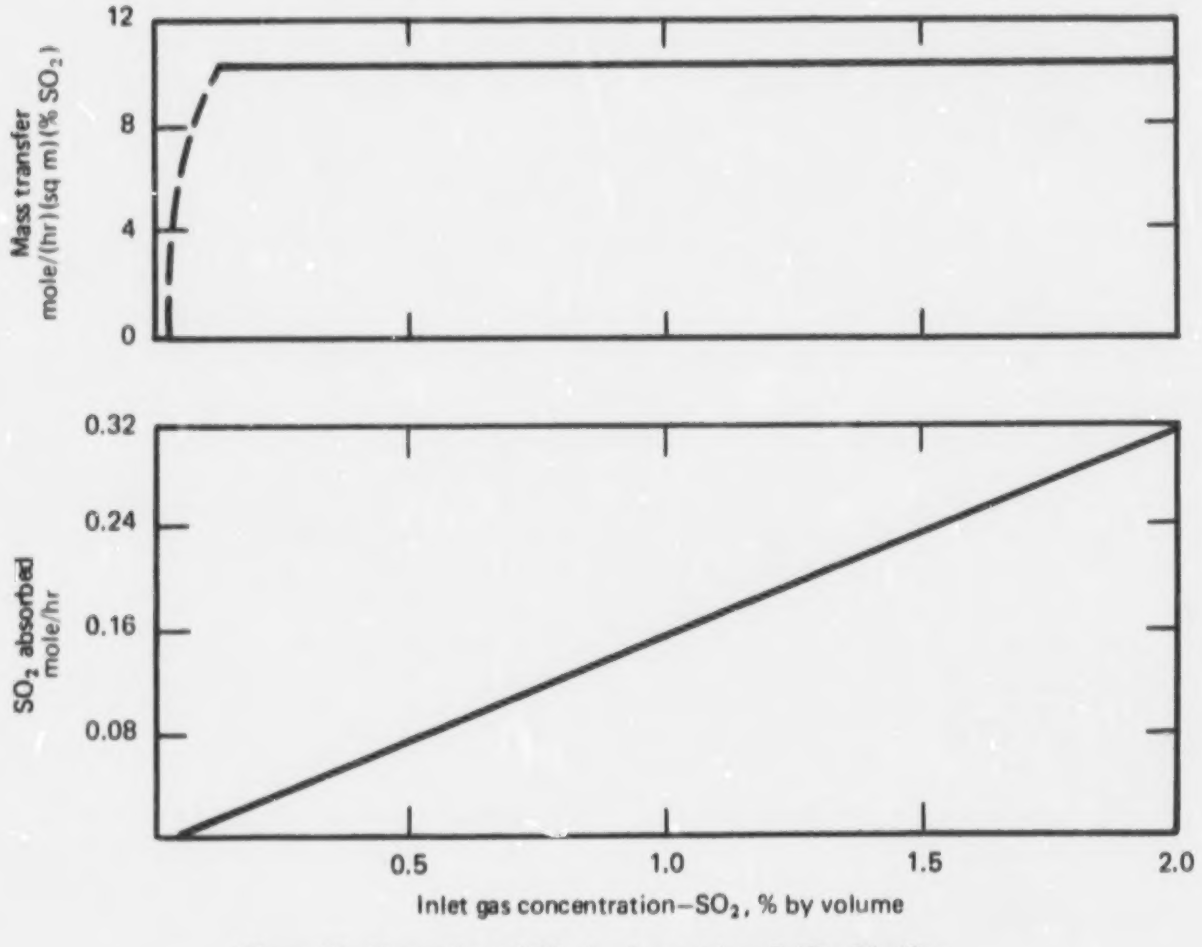
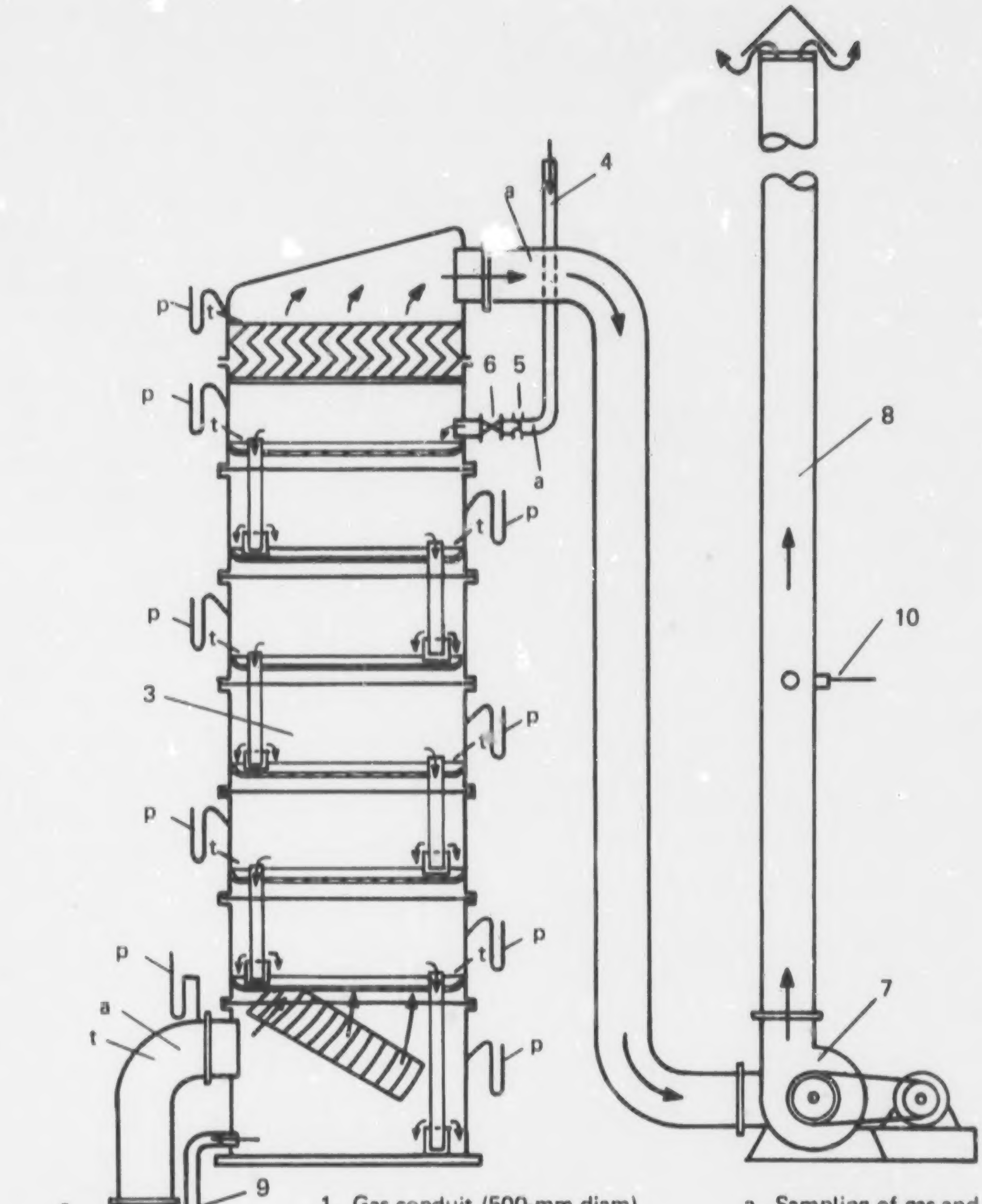


Figure 29. Absorption of SO_2 by Ammonium Sulfite-Bisulfite Solution in Wetted-Wall Absorber at Varying Concentrations of SO_2 in the Inlet Gas (11)



1. Gas conduit (500-mm diam)
2. Disc damper
3. Bubble absorber
4. Solution input pipe
5. Diaphragm
6. Control valve
7. Blower
8. Exhaust pipe
9. Saturated-solution pipe
10. Pitot tube with micromanometer

a. Sampling of gas and solution for analysis
t. Temperature measurement
p. Pressure measurement

Figure 30. Sieve-Plate Scrubber Tested by Chertkov *et al* (12)

larger, but removal of smaller particles is necessary for good plume appearance since about 30% of a typical fly ash is less than 10 microns in size. A 100-g sample of this ash would have approximately the following particle distribution:

Particle size microns[a]	Weight in fly ash, g	Number of particles
0.5	0.13	8.1×10^{11}
1	0.37	2.9×10^{11}
2	1.5	1.5×10^{11}
3	2.5	7.4×10^{10}
4	3.5	4.3×10^{10}
5	1.5	9.5×10^{9}
6	3.5	12.9×10^{9}
7	3.5	8.1×10^{9}
8	4.5	7.0×10^{9}
9	4.0	4.4×10^{9}
10	5.0	4.0×10^{9}
20	20.0	2.0×10^{9}
30	12.0	3.5×10^{8}
40	8.0	1.0×10^{8}
50	8.0	5.0×10^{7}
70	9.0	1.7×10^{7}
100	3.0	2.4×10^{6}
+100[b]	10.0	2.9×10^{6}

[a] Assumes particles smaller than 0.5 micron are 0.5 micron in diameter, particles smaller than 1 micron and larger than 0.5 micron are 1 micron in diameter, etc., to 100 microns.

[b] Assumes all +100-micron particles to be 150 microns in size.

A crossflow impingement plate scrubber with three plates and operating at a pressure drop of 6 in of water should remove (according to manufacturer's claims):

Micron size	Percent removal
+20	100
20	99.8
10	99.5
5	98.6
4	98
3	97
2	96
1	93
0.5	85

This scrubber would remove 99.5% of the wt of dust but only 89.5% of the number of particles. Operation at a higher pressure drop would result in a higher efficiency for small particles (figure 31), but in most cases the added expense probably would not be justified since removal of 99.5% (wt basis) by electrostatic precipitators is normally adequate.

The volume of gas to be scrubbed is quite large; stack gas flow rates for 200-, 500- and 1000-mw units are 533,000, 1,332,000, and 2,664,000 actual cubic feet per minute (acfm), respectively, at 118°F, the estimated scrubber exhaust temperature. To simplify gas distribution, the number of scrubbers/boiler should be as small as possible. Table 10 shows scrubber combinations for the three power plant sizes. The turndown ratio for the scrubbers is based on operation of the power plant at reduced load, as low as 30% of design. (A typical 200-mw unit has six coal pulverizers and can be operated with as few as two of them, giving a load of about 60 mw.) Only a limited number of manufacturers are presently capable of supplying scrubbers as large as those required; the turbulent bed and crossflow impingement scrubbers are the only types available at this time in sizes up to 500,000 cfm. However, scrubber sizes offered are increasing as manufacturers work with the problem. A venturi scrubber manufacturer has recently offered a 450,000-acfm unit.

A comparison of different scrubber types is given in table 11, showing the dust-removal capabilities, pressure drop, and turndown ratios of each. For staged operation it is desirable to have all the stages in a single scrubber shell to reduce investment, which is easier to accomplish for some scrubbers than for others. The countercurrent sieve (with downcomers) and crossflow sieve (figure 32) are the easiest as the weir overflow from each tray, part of the basic design, accomplishes the desired separation of liquor from gas so that the liquor can be recirculated to the same stage. For other scrubber types—countercurrent packed, countercurrent sieve without downcomers, TCA mobile bed, and Hydro-filter mobile bed—a special liquor collection tray must be placed under each stage (figure 33). Still other types—crossflow packed, cocurrent packed, venturi, spray towers, and orifice—present special problems in using liquor-collection trays.

Although any of these types might be adapted to staged operation, it was considered that those requiring special collection trays would have the disadvantage of extra pressure drop introduced by the trays. Therefore, the sieve tray types were favored. Chertkov obtained good operation with a sieve plate absorber and his results appear to be as good or better than those reported for other scrubber types by other workers, although the data are difficult to compare because of differing test conditions.

In regard to the two applicable sieve tray types, the sieve tray with downcomers gives the required sulfur dioxide absorption with a minimum pressure drop. The impingement type of cross flow sieve has a higher dust-removal efficiency, however, and is therefore considered to be best suited to the ammonia scrubbing process. Consequently, it was used as the basis for this conceptual design study.

Table 9. Variation of the Coefficient of Absorption with Decrease in Chemical Capacity of the Absorbing Solution[a] (12)

$SO_2:NH_{3eff.}$ in the input soln.	$NH_{3eff.}$, moles/100 moles H_2O	Average soln. temperature, °C	Average coefficient of absorption K^I, moles SO_2/m^2-hr-% SO_2
0.78-0.82	10	27	1620
0.28-0.84	10	27	1820
0.84-0.86	8.8	30	1320
0.88-0.90	7.6	26	970
0.90-0.92	7.3	26	635
0.92-0.96	5.7	25	200

[a] The linear gas rate in the total cross section was 1.5-2 m/sec.

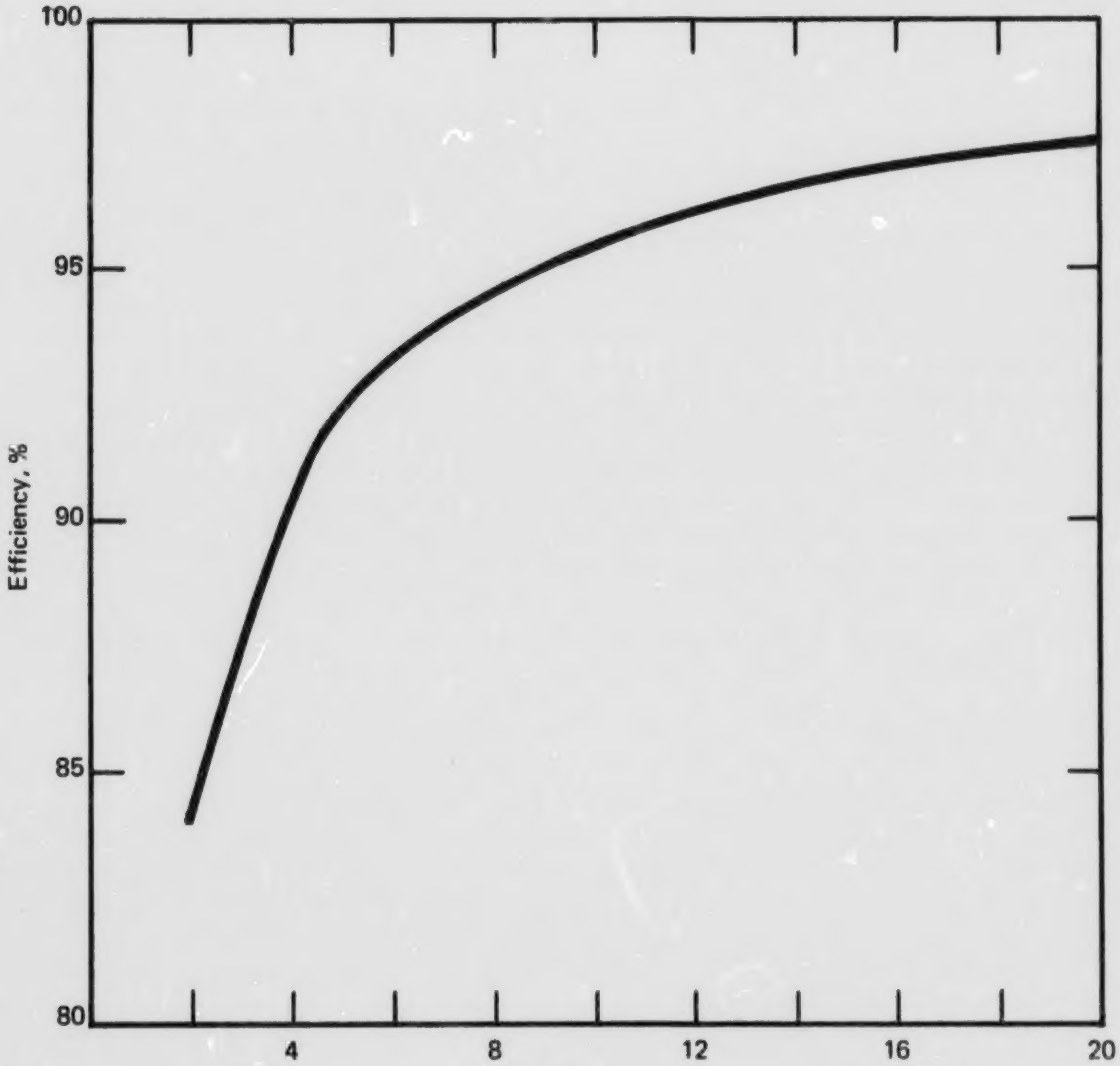


Figure 31. Collection efficiency[a] for 1-Micron Particles in Impingement-Type Scrubber

---

[a] Data from W. W. Sly Manufacturing Company (Catalog 151).

Table 10. Comparison of Scrubber Combinations

Plant size, mw	Assumed number of scrubbers	Design capacity/ scrubber, acfm	Gas flow at maximum turndown, acfm[a]	Volumetric turndown ratio required for each scrubber in operation	Approximate number of scrubber manufacturers[b]
200	1	533,000	160,000	3.33	2
200	2	266,500	160,000	1.67[c]	4
200	4	133,250	160,000	1.67[c]	6
500	2	666,000	400,000	1.67	2
500	4	333,000	400,000	1.67[c]	3
1,000	4	666,000	800,000	1.67[c]	2

[a] Assuming scrubber system would be operated at a minimum capacity of 30% of design.
[b] Presently known manufacturers for scrubbers of the sizes required.
[c] Turndown ratio required for each scrubber when using only one-half of the scrubbers at minimum system flow.

Mist Eliminators—The removal of liquid entrained in the scrubber exit gas serves three purposes:

1. Reduces the load on the stack gas reheater.
2. Decreases the deposition of liquid in the fan and in ducts located downstream from the scrubber.
3. Reduces amount of solids discharge by removing the dissolved solids contained in the mist which, after reheating, would be emitted to the atmosphere as dust.

The mist emitted by a wet scrubber would be comprised of liquid particles ranging from about 10 microns to 60 microns in diameter; particles smaller than 10 microns would not normally be produced unless water were condensed from the flue gas. With no mist removal from the scrubber exhaust, the gas would contain about 0.012 lb of entrained liquid/cu ft of gas. Use of a 95% efficient demister would reduce the heat required for reheat by about 3 million Btu/hr or about 4% of the total required for reheat to 250° F.

The mist eliminator should have the following characteristics:

1. A removal efficiency of at least 70% for 10-micron liquid particles and an overall efficiency of about 95%; above this the high capital cost is not justified by the advantages.
2. The ability to flush (with the collected mist) any undissolved solids collected in the separator.

Several types of mist eliminators were evaluated. The simplest and most common is the impingement vane type, the shape of the vanes and their arrangement cause impaction and coalescence of the mist. Other types of entrainment separators evaluated were the swirl vane, wire mesh (York), fiber bed (Brink), cyclonic, and packed bed (6-12 in of Tellerettes, Pall Rings, or others).

A comparison of the mist eliminators is shown in table 12. From this it appears that the vane types offer the lowest investment and best plugging resistance at acceptable pressure drops; overall removal efficiency should be about 95%. The Brink type is more efficient than justified for this application. The wire mesh and packed-bed entrainment separators could be used but should be equipped with a means for flushing with fresh water to remove solids collected on the mesh or packing. The cyclonic type (swirl chamber or tangential scrubber outlet) would probably not give an overall efficiency of 95%.

An impingement vane mist eliminator was selected for use with the sieve plate scrubber in the conceptual design.

Equipment for Reheating Gas—Alternate methods studied for reheat of the stack gas were:

1. Install a combustion system at the base of the power plant stack for burning natural gas, oil, or coal and mix the combustion products with the scrubber exit gas.

The main advantages for this method are low investment, flexibility in degree of reheat, minimum added pressure drop, low maintenance, and good reliability. Disadvantages are fuel cost, introduction of objectionable components (SO_3, SO_2, ash) into the gas, and fuel supply problems. Natural gas is the most expensive fuel but the added cost might be justified on the basis of convenience and clean combustion. However, gas would not be available at many power plants. Oil would be less expensive but receiving, storing, and handling would be a problem. Use of coal would result in the lowest fuel cost but would add more sulfur dioxide and ash to the stack gas. The fly ash emission could be minimized by firing the coal on a grate stoker.

2. Bypass the scrubber with part of the gas stream and mix this gas with the scrubber exit gas.

This procedure requires minimum investment and has essentially no operating cost. As discussed in the limestone - wet scrubbing study, however, bypass of the 310°F gas from a point after the air heater increases ground-level concentration rather than decreasing it. Bypass of gas from

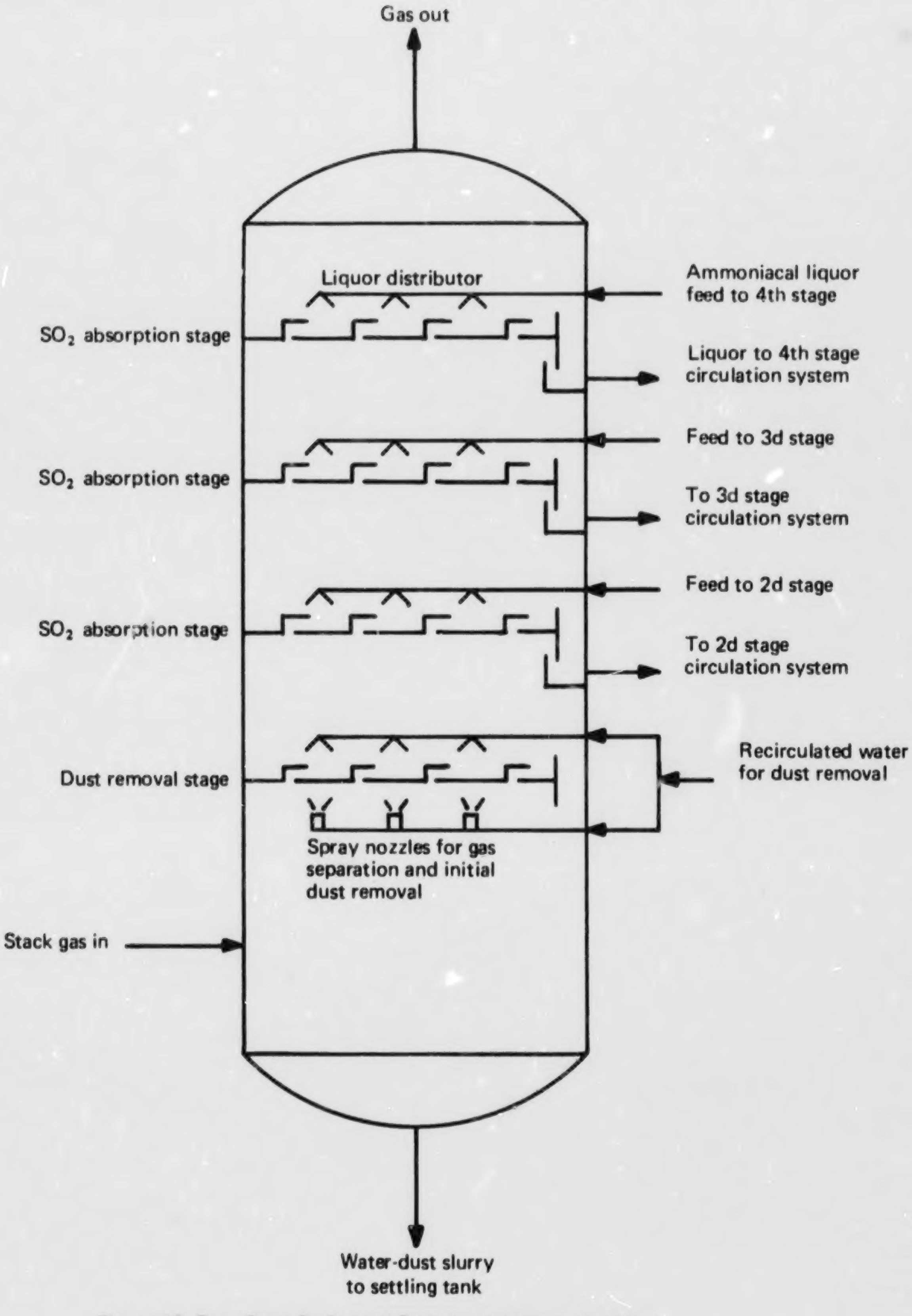

Gas out
Liquor distributor
Ammoniacal liquor feed to 4th stage
SO_2 absorption stage
Liquor to 4th stage circulation system
Feed to 3d stage
SO_2 absorption stage
To 3d stage circulation system
Feed to 2d stage
SO_2 absorption stage
To 2d stage circulation system
Recirculated water for dust removal
Dust removal stage
Spray nozzles for gas separation and initial dust removal
Stack gas in
Water-dust slurry to settling tank

Figure 32. Four-Stage Perforated Plate-Impingement Scrubber with Separate Circulation of Liquor Streams

upstream of the air heater would be more effective but this would reduce boiler efficiency and possibly give rise to problems in removing the dust.

3. Use heat exchangers for direct transfer of heat from the scrubber inlet gas to the exhaust gas.

With this method, heat that would be wasted is recovered. Further advantages are reduction in the amount of water required for evaporative cooling, a corresponding reduction in gas volume, and, except for maintenance, no labor requirement. Disadvantages are the large heat exchanger required (because of low transfer coefficient and temperature differential), high pressure drop, and possibility of fouling—which would lead to low efficiency and high maintenance cost. Corrosion by sulfur trioxide would be a problem with mild steel exchangers.

4. Use a cyclic-liquid heat exchange system with heat transfer from the inlet gas to treated water and from the water to the scrubber exhaust gas.

The better heat transfer cofficient would permit use of smaller exchangers than those required for gas-gas exchange and the smaller surface would reduce pressure drop and maintenance.

5. Heat with steam from the turbine cycle in a heat exchanger at the scrubber outlet.

This method would require additional coal firing in the boiler to generate the extra steam and modification of the turbine to allow higher than normal extraction rates. Extensive modification of existing units would be impractical, but in a new plant a system could be included to provide the steam required.

Use of steam for reheat would require relatively small heat exchangers installed only on the scrubber discharge, where the gas is relatively clean. Corrosion, fouling, and pressure drop would be minimized. The main disadvantage is the added fuel requirement.

6. Use a cyclic system comprised of heat exchange towers where liquid or solid particles are sprayed into the gas stream ahead of the scrubber and the sensible heat gained by the particles is transferred to the scrubber exit gas in a similar chamber.

Table 11. Scrubber Comparison

Scrubber type	Usual application	Approx. maximum inlet gas dust loading, gr/cu ft	Approx. dust-removal efficiencies[a]			Approx. pressure drop for 90% SO_2 removal, in. water[b]	Suitable for new power plants without upstream mechanical dust collection	Approx. turndown ratio[c]
			1-micron particles	2-micron particles	5-micron particles			
Countercurrent packed[d]	GA	1-2	0	0	95	11	No	1.2
Cocurrent packed[d]	GA	2	0	0	95	10	No	5.0
Crossflow packed[d]	GA	3-4	0	0	95	8	No	5.0
Countercurrent sieve	GA and PR	10	85	92	95	9	Yes	1.2
Crossflow sieve (impingement type)	GA and PR	100	93	96	98-99	9	Yes	1.2
SF venturi	GA and PR[a]	+100	97	99	99+	24	Yes	1.3
Splash plate venturi	GA and PR[a]	+100	97	99	99+	24	Yes	2.0
Cyclonic spray	GA and PR[a]	15-20	30	70	94	10	No	2.0
Spray tower	GA and PR[e]	15	20	60	90	12	No	4.0
Mobile bed Hydro-filter	GA and PR	25	92	98	99+	26	Yes	1.5
Mobile bed TCA	GA and PR	25	92	98	99+	13	Yes	1.5
Orifice	PR	25	35	75	93	24	No	1.2

[a] When operating at pressure drop required for 90% SO_2 removal.

[b] For process A (three absorption stages) and including 1 in of pressure drop for each liquor-collection tray, if required (see figure 33).

[c] Ratio of design volume rate to minimum allowable volume rate.

[d] These scrubbers will not remove particles smaller than 3 microns unless nucleation is effected by condensing water vapor.

[e] For highly soluble gases only.

Key: E (Excellent), G (Good), F (Fair), NR (Not Recommended), GA (Gas Absorption), PR (Particulate Removal), Y (Yes), N (No), UC (Uncertain).

Table 12. Comparison of Demisters

Type	Removal efficiency for 10-micron mist particles, %	Pressure drop, in. of water[a]	Approx. cost for 200-mw installation, $	Resistance to solids plugging
Impingement vane	70	0.4	3,500	Good
Swirl vane	70	0.3	3,000	Good
Wire mesh (York)[b]	98-99	0.8	12,000	Fair
Fiber bed (Brink)	100	7.0	75,000	Poor
Packed bed[c]	90	0.1-0.2	9,000	Fair
Cyclonic	60-70	0.5-1.0	5,000	Good

[a] Required for removal efficiency shown for 10-micron particles.
[b] Six in-thick bed.
[c] Eight in of packing.

With this system, there would be no heat exchangers to foul or corrode and the pressure drop would be low. With a liquid, partial dust removal could be effected by filtering or centrifuging the liquid from the "hot" tower. However, a low vapor pressure over the liquid would be required to prevent carryover to the scrubber and the liquid should be nonflammable or have a high kindling temperature to prevent fire hazard. Use of solid particles would require a material with good abrasion resistance to withstand the rough handling.

Insufficient information is available to prepare a cost estimate on this reheat method.

Based on the cost comparison shown below, the cyclic-liquid heat exchange method of reheat was chosen.

Technique[a]	Fuel, $	Fan and power, $	Labor, maintenance & overhead, $	Capital charges, $	Total, $	$/ton coal burned	Reheat invest., $
Direct, natural gas	247,000[b]	3,100	5,300	38,400	293,800	0.49	265,000
Indirect, liquid-gas	–[c]	31,000	23,000	131,200	185,200	0.31	905,000
Indirect, gas-gas	–[c]	55,000	64,200	333,000	452,200	0.75	2,300,000
Indirect, steam-gas	147,600[d]	14,000	16,800	60,900	247,300	0.41	420,000
Direct, coal stoker	109,200[e]	3,400	31,000	65,200	208,800	0.35	450,000

[a] 200-mw power plant; reheat to 250° F; 440 M scfh.
[b] Natural gas at $0.40/MM Btu.
[c] Indirect liquid-gas and gas-gas utilize waste heat in exhaust gases.
[d] Steam at $0.30/MM Btu from 200-mw plant designed for excess process steam.
[e] Coal at $0.20/MM Btu.

Equipment Description

Gas Scrubbing and Reheat—For a new power plant, the scrubbing system would serve the dual function of particulate removal and sulfur dioxide absorption. In an impingement plate scrubber, about 99.0% of the particulates would be removed on the first tray, with recirculating water used as the scrubbing medium. Ammonia would be added to the stack gas upstream of the scrubber to neutralize sulfur trioxide absorbed on the dust-removal tray. A bypass duct would be provided around each scrubber to permit shutdown of a scrubber for inspection, cleaning, or maintenance.

For an existing power plant, the scrubbing system would serve the primary function of sulfur dioxide absorption and a secondary function of final dust removal subsequent to dust removal by mechanical collectors.

From English and Van Winkle (31), plate efficiencies for sulfur dioxide and ammonia were estimated using solution viscosities and densities derived from Chertkov and Pekareva (21) and Tans (78). Vapor pressure data were calculated for ranges of ammonium ion concentration and sulfite-bisulfite mole ratio using the formulas of West (94). Vapor-liquid concentration lines were plotted from these data and in conjunction with the efficiencies, calculations were made to determine both the number of plates required for 90% absorption of sulfur dioxide and the resulting loss of ammonia. The results indicate that, for processes A and C, three absorption stages would be required to remove 90% of the sulfur dioxide. For process B, four absorption stages would be needed to remove 90% of the sulfur dioxide and maintain a maximum content of ammonium bisulfite in the effluent liquor from the lower stage.

The validity of the estimated tray efficiencies was tested by developing a mass transfer model from the experimental

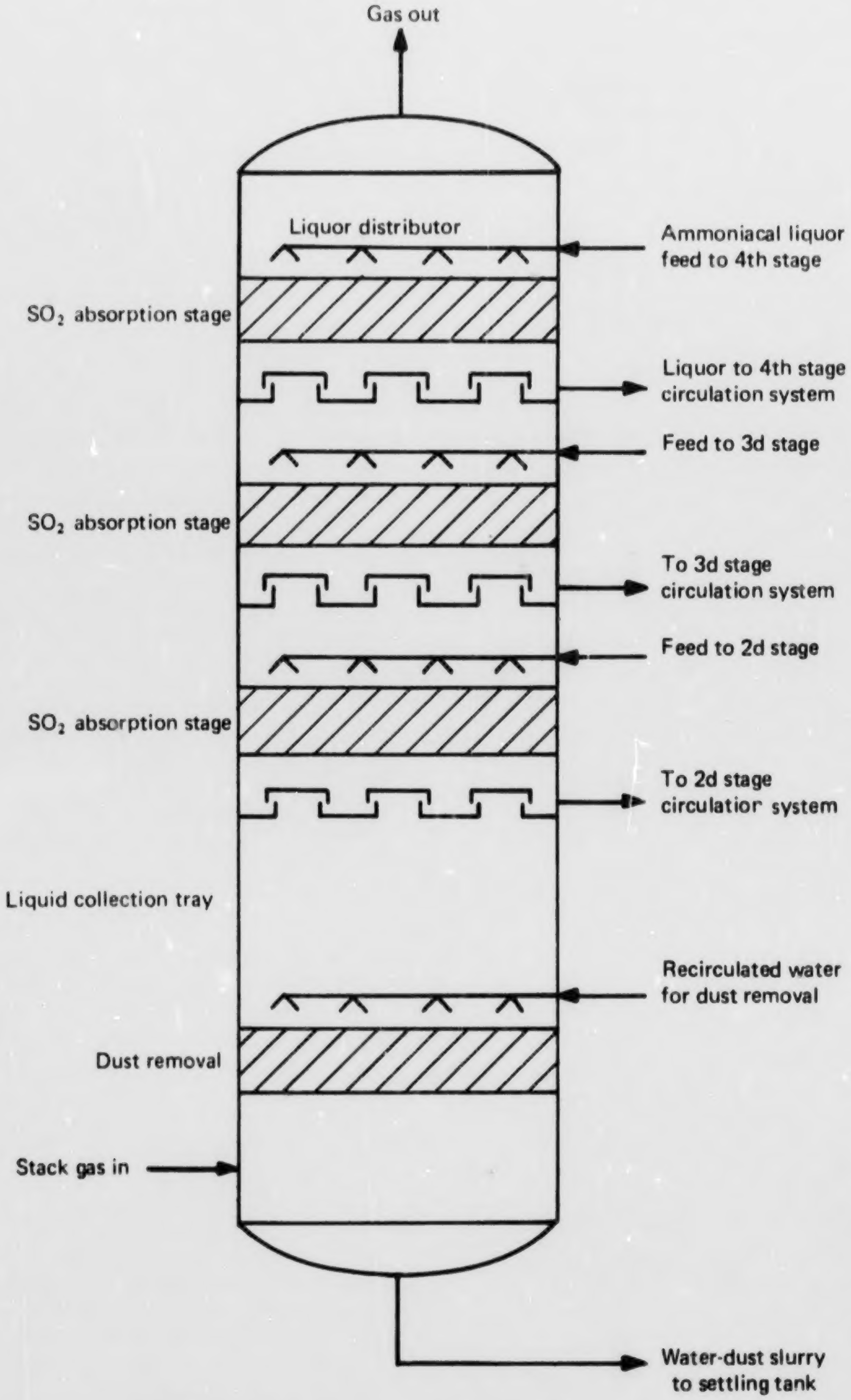

Gas out
Liquor distributor
Ammoniacal liquor feed to 4th stage
SO$_2$ absorption stage
Liquor to 4th stage circulation system
Feed to 3d stage
SO$_2$ absorption stage
To 3d stage circulation system
Feed to 2d stage
SO$_2$ absorption stage
To 2d stage circulation system
Liquid collection tray
Recirculated water for dust removal
Dust removal
Stack gas in
Water-dust slurry to settling tank

Figure 33. Four-Stage Scrubber with Gas-Liquid Separation Plates Under SO$_2$ Absorption Stages

data of Chertkov. As a first consideration, Chertkov (24) indicated that the liquid-phase resistance begins to have an effect on the mass transfer rate when the pH drops below 5.5-6.0 or the $SO_2:NH_3$ ratio is in the range of 0.7-0.83. Estimated solution compositions are shown in table 13. Two trays for the process A and C scrubbers and all of the trays for the process B scrubber are in the above pH range.

In 1959 Cherktov (12) reported the effect of $SO_2:NH_3$ ratio on tray efficiency at constant gas velocity and nearly constant temperature. It was assumed that the partial pressure of sulfur dioxide in the gas phase and the liquid rates were held essentially constant. A transfer model was developed on the assumption that the mechanism for absorption is as follows:

1. Solution of sulfur dioxide in water
2. Diffusion of sulfur dioxide to ammonia interface
3. Diffusion of ammonia to sulfur dioxide interface
4. Reaction

A two-film mechanism was used as the statistical representation of the performance:

$$K' = \frac{1}{\frac{1}{k_G} + \frac{m}{k_L}} \qquad (45)$$

where $k_G = f\,[(U_s - U_c)\,L^{n^1}]$
U_s = superficial velocity
U_c = minimum tray velocity
L = liquid rate
m = slope of equilibrium line

and

$k_L = f\,(e^{-nT})\,f^{11}\,(q)\,f^{111}\,(Cai)\,f^{iv}\,(L)$
T = temperature
q = excess ammonia
Cai = concentration of sulfur dioxide in solution in equilibrium with sulfur dioxide in vapor
L = liquid rate

Since $k_L \alpha \mu^{1/2}$ and μ (viscosity) for a water solution is proportional to exponent (-0.02 T), the function e^{-nT} is $e^{-0.01\,T}$. The k_L value is a function of L and because of tray traverse and weir overflow the effect of L will range in the exponential value of -1/3 to +1/3. The values for Cai and m were taken from the equilibrium compositions of the SO_2-NH_3-H_2O system. Data from Chertkov (12) were used in a regression analysis to define the best fit equation:

$$K' = \frac{1}{\frac{0.00846}{(U_s - 0.5)} + \frac{0.00044\,m \quad Cai^{0.75}}{2q\,(1.6\text{-}1.4\,q)\;e^{0.01\,T}}} \qquad (46)$$

Conversion of K' values to efficiencies was based on the relationship:

$$1 - E_{og} = \exp^{-}\frac{K'PZ}{\Theta m} = e^{-N_{og}} \qquad (47)$$

where E_{og} = removal efficiency
P = tower pressure
Z = tower height
Θ = residence time
N_{og} = number of transfer units

The conversion constants were calculated from the Chertkov data (12) with the assumption that solution on a tray is totally mixed.

Tray efficiencies were established from the relationship:

$$E_{og} = \frac{P\text{ inlet} - P\text{ outlet}}{P\text{ inlet} - P^*} \qquad (48)$$

where P = partial pressure of solute gas
P^* = partial pressure of gas in equilibrium with liquor

Values for N_{og} were calculated and $U_s\,N_{og}$ was plotted vs K' (figure 34). The following equation is a good approximation of the curve.

$$U_s\,N_{og} = 0.00192\,K' + 1.35 \qquad (49)$$

Tray efficiencies were then calculated as follows:

Table 13. Tray Composition Conditions

Process scheme	Plate	$(NH_4)_2SO_3$, g/mole	NH_4HSO_3, g/mole	NH_3, g/mole	SO_2, g/mole	$SO_2:NH_3$, mole ratio	H_2O, l
A-C	2	0.1402	0.1668	0.4472	0.3070	0.687	0.0496
A-C	3	0.0317	0.0429	0.1063	0.0746	0.702	0.0877
A-C	4	0.01035	0.01635	0.03705	0.0267	0.720	0.0956
B	2	0.0964	0.2285	0.4113	0.3249	0.79	0.0475
B	3	0.0714	0.1361	0.2789	0.2075	0.744	0.0662
B	4	0.0386	0.0613	0.1385	0.0999	0.721	0.0837
B	5	0.01525	0.02044	0.05094	0.03569	0.70	0.0941

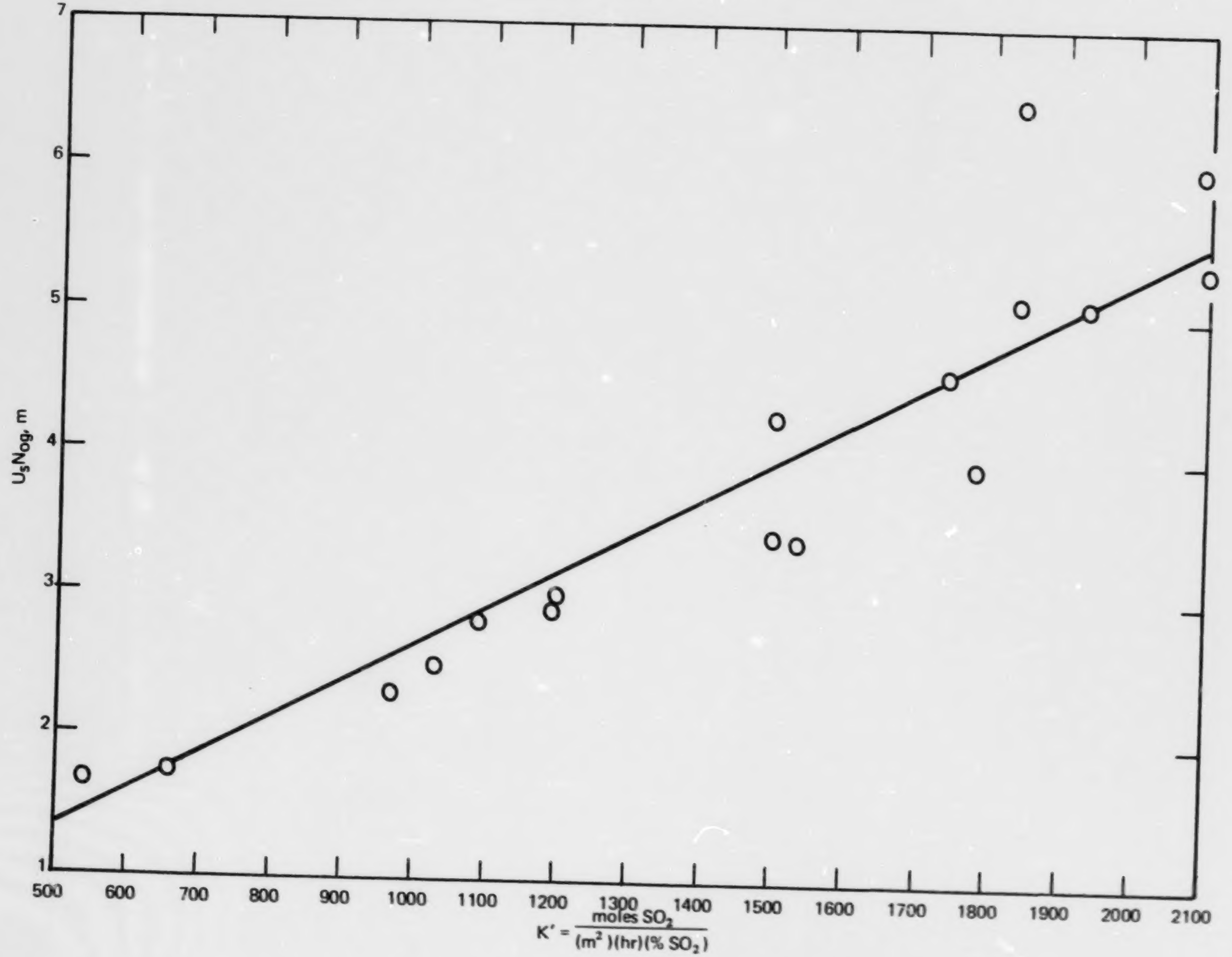


Figure 34. Relationship of N_{og} and K', Based on Chertkov Data for Sieve Tray Absorption of SO_2 in NH_3-SO_2-H_2O Solution

1. q, Cai, T and U_g were established for each tray.
2. K' was calculated from the above semiemperical equation based on Chertkov data.
3. U_g N_{og} was calculated using the linear relationship with K^l.
4. E_{og} was determined by conversion of the N_{og} values.

The predicted tray efficiencies are shown in table 14. Based on these results, the design is adequate.

The assumed 500-mw power plant would be fitted with four recovery trains (one scrubber to each train). A typical plot plan for the plant is shown in figure Y69-A-10 in Appendix C. A plan and elevation view of the system are shown in figures Y69-A-8 and Y69-A-9, respectively, also in Appendix C. Each of the four scrubbers would handle 333,000 acf of gas at 118° F and full power plant load. The units are four-plate (processes A and C) or five-plate (process B), countercurrent Impinjet gas scrubbers manufactured by the W. W. Sly Manufacturing Company (figure 35). Each scrubber has a 20- by 40-ft rectangular cross section, is 27 (processes A and C) or 30 (process B) ft high, and is constructed of mild steel internally coated with a coal tar epoxy resin.

Internal impingement baffle plates and spray assemblies are of stainless steel construction. The perforated impingement plates have holes about 0.1 in in diameter on about 3/16-in centers. They are installed in a stepdown design to minimize the liquid gradient. The scrubbers are designed for 9-in (processes A and C) or 11-1/4-in (process B) pressure drop with an L/G volume ratio of 2 (gal/1000 acf) on each tray. At reduced load, one or more of the scrubbers will be shut down by closing a louvered-type damper installed at the scrubber inlet.

The absorption stages have common recirculation tanks for each pair of scrubbers. For processes A and C, six tanks are required and for process B, eight tanks. Each tank has an operating capacity of 5000 gal and is 10 ft in diameter by 7 ft high. The settling tank, which collects fly ash slurry from all four scrubbers is 15 ft in diameter by 7 ft high, has an operating capacity of 10,000 gal, and is equipped with a cone bottom for discharge of solids from the system through a variable-speed pump. The system is designed for 12% solids in the ash slurry to the pond. Scrubber liquor circulating pumps deliver 680 gal/min split between each pair of upper plates. The recirculation pump for the settling tank delivers 765 gal/min. Installed spares are provided. Monitors for measuring pH are installed in the circulation tanks.

Table 14. Estimated Tray Efficiencies

Tray	K'	U_sN_{og}	N_{og}	$e^{-N_{og}}$	E_{og}, %
A-C-2	520	1.4	0.94	0.4	55
A-C-3	1,040	2.6	1.73	0.18	82
A-C-4	800	2.1	1.4	0.25	75
B-2	930	2.4	1.6	0.2	80
B-3	1,130	2.8	1.86	0.16	84
B-4	1,140	2.8	1.86	0.16	84
B-5	1,070	2.7	1.8	0.17	83

The gas is reheated by mild steel, finned-tube heat exchangers installed in the ductwork on each side of each scrubber. The tubes have an outside diameter of 2 in and ¾-in fins spaced five/in. Based on a coefficient of 8 Btu/hr/sq ft, 197,000 sq ft of surface area is required. The tubes are 20 ft long and are arranged in 11- by 16-ft tube bundles.

As mentioned earlier, a small amount of ammonia is added to the gas stream before the cooler to react with the sulfur trioxide in the gas stream and thereby prevent sulfuric acid corrosion.

Circulating water (treated boiler water) at a rate of 710 gal/min is used to transport heat from one exchanger to the other. In a cold climate, antifreeze should be added for periods when the system is shut down. The design temperature profile is:

Heat removal, °F	
Gas	310-172
Liquid	143-280
Reheat, °F	
Gas	115-250
Liquid	280-143

Conversion of Scrubber Solution to Ammonium Sulfate––For processes A and C, the scrubber solution is oxidized to convert the sulfite to sulfate for further use. Since oxidation in the scrubber is desirable, a packed scrubber would be a better choice than a sieve plate type to improve the oxygen:sulfur dioxide absorption ratio. However, even if an oxidation promoter were used, complete conversion would be difficult to achieve and further treatment would probably be necessary. Moreover, residual dust in the scrubber solution would be a problem in operating packed scrubbers because of tendency to plugging. The most practical approach appears to be provision of a scrubber for effective dust and sulfur dioxide removal and to carry out the oxidation as a separate step.

The JECCO method (43) was selected as the basis for design of the oxidizing system. Sufficient information was obtained for preparation of capital and operating cost estimates but details were not made available. It is assumed that a firm design could be provided on a fee basis by JECCO.

Before oxidation, the ammonium bisulfite in the scrubber effluent is converted to ammonium sulfite by addition of ammonia in a neutralizer. Conversion is necessary to prevent loss of sulfur dioxide during oxidation. The neutralizer is a lined, mild steel vessel 6-½ ft in

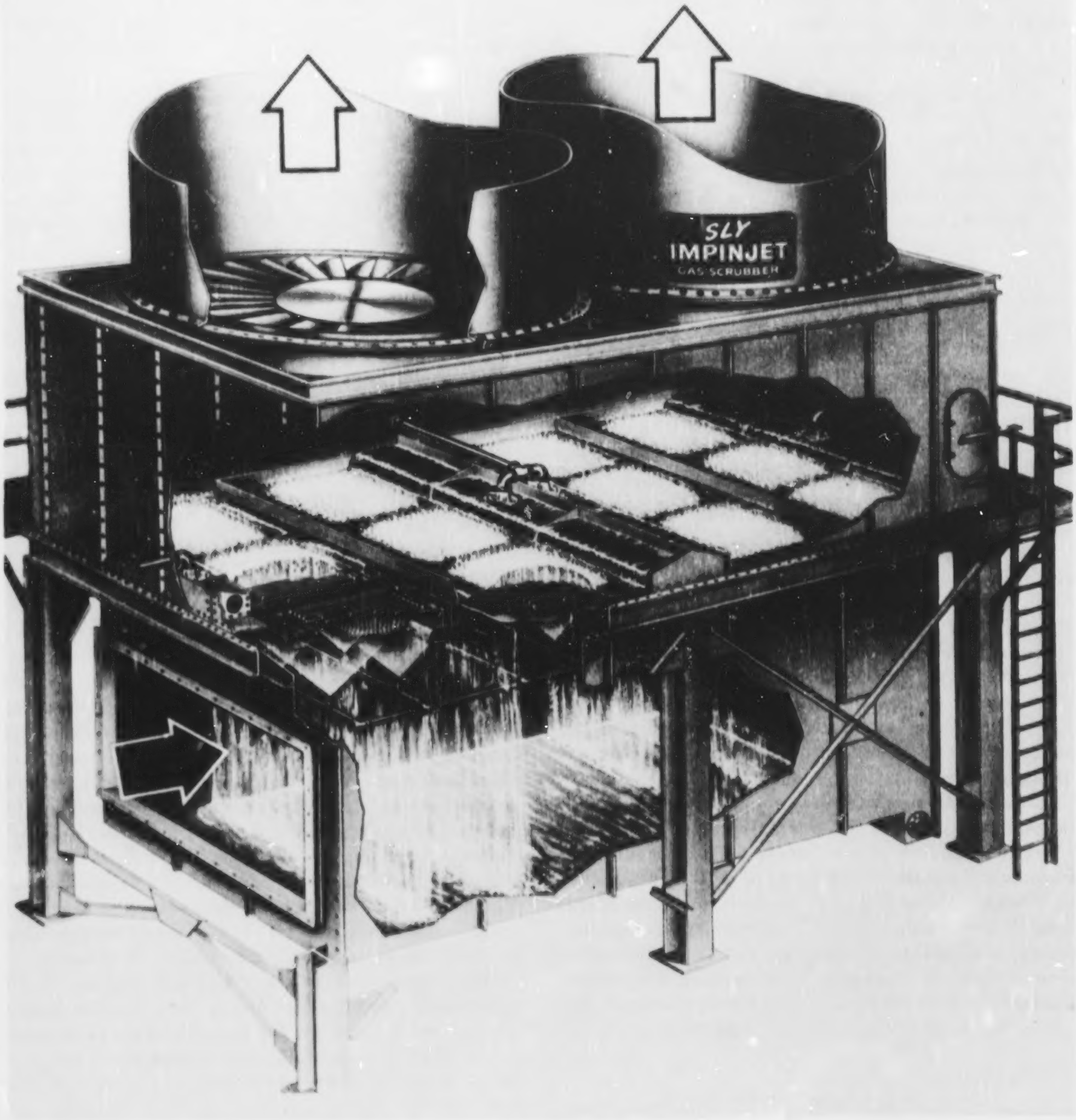

SLY
IMPINJET
GAS SCRUBBER

Figure 35. Typical Sly Impinjet Scrubber

diameter and 10 ft high with dished head and bottom. Ammonia is added through spargers in the bottom. The vessel is vented to a point upstream of the scrubbers to recover ammonia in the off-gas. The salt concentration in the solution is adjusted to 40% to prevent crystallization of ammonium sulfate in the oxidizer.

The stream is split to two parallel oxidizers comprised of stainless steel pressure vessels 7 ft in diameter by 32 ft high with dished heads and bottoms. Air is introduced through mechanical atomizers into the solution, which is maintained under a pressure of 100 psig. Air is supplied to each vessel by 6300 scfm centrifugal compressors with 1500-horsepower drives. Heat of reaction is removed by circulation of the solution through a 3000-sq-ft water-cooled exchanger to maintain a temperature of 185° F. Temperature control is required to improve solubility of oxygen.

It was assumed that the oxidizer would be located adjacent to the scrubber and that the ammonium sulfate solution would be pumped to surge storage at the fertilizer production facilities in a separate area.

For process B, oxidation in the scrubber should be minimized because sulfate formation reduces the amount of sulfur dioxide which can be recovered by acidulation of the scrubber effluent. The sieve plate scrubber should provide conditions for a low degree of oxidation; 10% conversion to sulfate in the scrubber was assumed. A high degree of conversion of ammonium sulfite to bisulfite should be achieved by recirculation of scrubber liquor around the bottom stage of the scrubber where sulfite will be exposed to the maximum sulfur dioxide concentration in the gas. For design of the decomposition and stripping processes an $SO_2:NH_3$ ratio of 0.72 was assumed.

Sulfuric acid (93%) is reacted with the scrubber effluent in a stainless steel sieve plate column 7-½ ft in diameter by 20 ft high. Liberated sulfur dioxide is stripped from the solution by passing air through the liquid on the plates; air is provided at a rate of 4800 scfm by a centrifugal blower.

The sulfur dioxide-air mixture (30% SO_2) evolved from the stripping column is processed in a standard contact sulfuric acid plant, except that no sulfur burner is needed. Approximately 7500 scfm of gas is treated to produce about 400 tons/day of acid; two-thirds of the production is consumed in the acidification step and the remaining third is transferred to the fertilizer plant. Storage for 2 days of acid production is provided.

The solution from the stripping column is essentially a 45% solution of ammonium sulfate with less than 0.5 g/l of sulfur dioxide. It is pumped at a rate of 112 gal/min (15 tons/day of ammonium sulfate) to the fertilizer process.

Decomposition of Ammonium Sulfate (Process C)——In processes A and B, the ammonium sulfate is used directly as a 40% solution in the fertilizer process. In process C, further treatment of the liquor is necessary. The solution is concentrated and ammonium sulfate crystallized in a double-effect vacuum evaporator-crystallizer. The crystals are separated in a continuous centrifuge and the liquid phase returned to the evaporator. Damp crystals are fed by a screw conveyor into a two-stage submerged combustion vessel where the ammonium sulfate is decomposed at a temperature of 700° F; a retention time of 1 hr is required. Ammonia in the exhaust gas is removed by scrubbing and recycled. The ammonium bisulfate, a melt at decomposition temperature, is quenched and dissolved in water in an insulated tank equipped with an agitator. The hot (220° F) ammonium bisulfate liquor is pumped to an extractor where it is used instead of nitric or sulfuric acid for digestion of phosphate rock.

Raw Material Storage——The primary raw materials are ammonia and phosphate rock. Ammonia is received in railroad cars in liquid form and stored in an insulated, atmospheric pressure tank (at -28° F). A 3-week supply is provided, amounting to the following quantities (for the 500-mw unit and 3.5% S coal assumed):

1. Process A - 8000 tons
2. Process B - 5500 tons
3. Process C - 4500 tons

Phosphate rock is received in railroad cars and stored in a bin in the extraction unit. About 2 days' storage is provided.

Nitric Acid Production——The nitric acid requirements for processes A and B are produced from ammonia in a standard commercial plant designed to produce 60% acid. Product storage capacity for 2 days' production is provided.

Acidulation, Precipitation, and Filtration——The primary function in acidulation is to react phosphate rock with an acid to form a soluble fertilizer intermediate and insoluble calcium sulfate (gypsum); the latter is removed by filtration. The equipment required for this function and the following fertilizer production steps is of standard design and will not be described in detail. The flow scheme for this unit varies with each of the three processes:

Process A——Phosphate rock is reacted with nitric acid to form calcium nitrate and phosphoric acid, both in solution. Calcium nitrate is subsequently reacted with ammonium sulfate (from the oxidizers) to form a solution of ammonium nitrate (with phosphoric acid and water) and a precipitate of gypsum. The gypsum is separated by filtration.

Process B——A portion of the rock is reacted with nitric acid as in process A. Sulfuric acid is added in a second stage of rock extraction to complete the acidulation and form phosphoric acid and gypsum. Calcium nitrate formed in the first extraction stage is reacted with ammonium sulfate as in process A. The filtrate (after removal of gypsum) contains more phosphoric acid and less ammonium nitrate than in process A.

Process C—Phosphate rock is acidulated with ammonium bisulfate to form phosphoric acid and ammonium sulfate in solution and a precipitate of gypsum that can be removed by filtration.

Gypsum Disposal—The gypsum filter cake is sluiced in the acidulation unit and pumped as a 20% slurry to a gypsum disposal pond. The pond is sized to hold a 10-yr supply of gypsum. For process A in a 500-mw power plant, the pond is 1650 ft long and 1100 ft wide with dikes 50 ft high. A seepage ditch encircles the pond and a portable pump is used to return the seepage. The pond is equipped with internal overflow weirs to control the level and collect clarified water. This water is returned for sluicing gypsum. Excess overflow is treated with lime to neutralize any acids.

Neutralization and Prilling (Processes A and B)—The filtrate from the acidulation unit is neutralized by reacting ammonia with phosphoric acid to attain an $NH_3:H_3PO_4$ mole ratio of about 1.37. The neutralized stream is pumped to a falling-film evaporator for concentration to about a 99.5-99.7% melt. The melt is sprayed into the top of an induced draft prilling tower where it falls through an upward flow of air. The resulting prills are subsequently cooled and screened with the product size going to storage and the oversize and undersize sent back to the concentrator as a solution. Air pollution abatement facilities are included.

Granulation (Process C)—The granulation unit in process C is similar to the drum ammoniator-granulator commonly used in manufacture of diammonium phosphate. Filtrate from the acidulation is neutralized to an $NH_3:H_3PO_4$ mole ratio of about 1.37 and fed to the granulator. Additional ammonia is added to raise the mole ratio to about 1.8. The solids from the granulator are dried and screened, the product-size material is cooled and sent to storage, and the oversize solids are crushed and recycled to the granulator along with undersize. Some product size is recycled as required to control the granulation step. Air pollution abatement facilities are provided.

Fertilizer Storage and Shipping—Product storage is provided for 90 days of production. For process A in a 500-mw plant, the storage building holds about 60,000 tons. The building is 110 ft wide and 830 ft long with 10-ft-high concrete walls. The floor is concrete and the upper siding and roof is transite attached to a steel framework. Fertilizer solids are distributed in the building by an 800-ft tripper-conveyor.

Fertilizer is removed from the building with a payloader and fed to the bulk shipping building. The solids are screened and the oversized crushed and rescreened prior to shipment by railroad cars. The shipping rate is 300 tons/hr. Car pullers are used to move railroad cars to the loading station and railroad scale.

INVESTMENT AND OPERATING COST

Based on the design assumptions and equipment selected, investment and operating cost estimates were made for several different combinations of the more important variables.

Investment

Estimates were prepared for seven different combinations of the three major variables that affect investment—power unit size, power unit status (new or existing), and sulfur content of coal.

Unit size, mw	Status	Sulfur content of coal, %
200	Existing	3.5
500	New	2.0
500	New	3.5
500	Existing	3.5
500	New	5.0
1,000	New	3.5
1,000	Existing	3.5

Each of the seven combinations was estimated for processes A, B, and C, making a total of 21 investment estimates; these are given as tables B-1—B-21 in Appendix B. Operating life of the new units is assumed to be 35 yrs. Remaining life of the existing units is considered to be 27 yrs for the 200-mw units and 32 yrs for the 500- and 1000-mw sizes.

The estimates are based on vendor quotations and authoritative publications. The process equipment costs were first determined and installation expense then added to yield the direct installed costs. Utilities distribution, but not generation facilities, was included. Indirect costs, including estimated contractor fees, overhead, engineering design, and arbitrary contingency, were then calculated according to the following schedule.

	Indirect investment costs, percentage of direct installed cost				
		500-mw		1,000-mw	
	200-mw existing unit	Existing unit	New unit	Existing unit	New unit
Engineering design	10	10	8	8	7
Contractor fees and overhead	15	15	12	12	10
Contingency	10	10	10	10	8
Total	35	35	30	30	25

Table 15. Total Fixed Investment of Ammonia Scrubbing-Fertilizer Manufacturing Facilities for Existing Power Plants[a]

	Unit size					
	200-mw		500-mw		1,000-mw	
Process	$ (M)	$/kw	$ (M)	$/kw	$ (M)	$/kw
A	12,520	62.6	22,320	44.6	36,550	36.5
B	11,428	57.1	20,191	40.4	32,904	32.9
C	9,589	47.9	17,329	34.6	26,646	26.6
Limestone - wet scrubbing	2,610	13.1	5,425	10.8	8,210	8.2

[a] 3.5% sulfur in coal.

The effect of plant size and process type on investment is summarized in table 15 (for existing plants and 3.5% sulfur in coal). Process A requires the largest investment and process C the least; however, it should be pointed out that the amount of fertilizer produced is greatest with process A and least with process C. The importance of this can be seen only after full examination of the profitability estimates given later, which take into account production rate, net sales revenue, and operating cost.

In comparison with other recovery processes, the range of $26.60-62.60/kw is quite high. The reason for this is that a finished product is made rather than an intermediate such as sulfuric acid, sulfur, or ammonium sulfate.

The overall fixed investments for installation in new power plants are given in table 16. Also given is the effective investment if credit is taken for eliminating electrostatic precipitators that are normally installed (99% efficiency assumed). Such a credit is based on the assumption that the scrubbers will remove dust to an acceptable degree.

The division of investment between the ammonia scrubbing and fertilizer manufacturing portions of the installations are shown in figures 36, 37, and 38. The fertilizer portion requires much more investment than the scrubbing section and accounts for most of the variation between processes.

The sulfur content of the coal burned is also important in investment requirement (figure 39). Doubling the sulfur content (2-4%) increases total investment by about 30%.

Operating Cost

The estimating of operating cost was complicated by the fact that, as discussed earlier, projects for sulfur dioxide removal may be financed on different bases—the regulated power industry basis, the unregulated chemical industry practice, or a combination of the two. This has a major effect on capital cost items such as depreciation and taxes. Because of this, four estimates were made for each of the 21 combinations of plant size, power unit status, sulfur content of coal, and process type. The four covered the following:

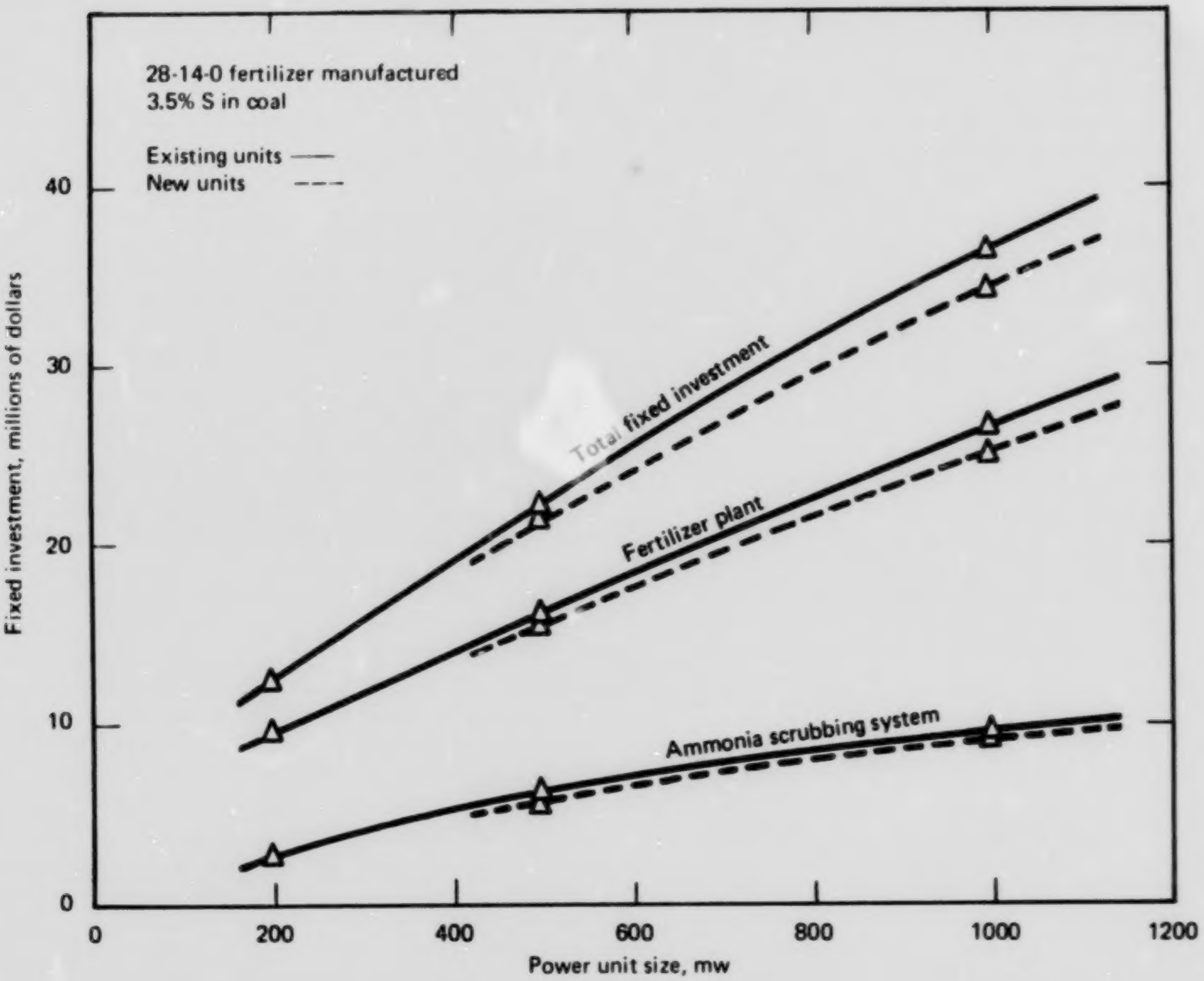


Figure 36. Effect of Power Unit Size on Ammonia Scrubbing - Fertilizer Plant Investment (process A)

Table 16. Total Fixed Investment of Ammonia Scrubbing-Fertilizer Manufacturing Facilities for New Power Plants[a]

	Unit size							
	500-mw				1,000-mw			
	Actual		After precipitator credit		Actual		After precipitator credit	
Process	$ (M)	$/kw	$ (M)	$/kw	$ (M)	$/kw	$ (M)	$/kw
A	21,470	42.9	20,565	41.1	34,500	34.5	32,950	32.9
B	19,689	39.4	18,784	37.5	31,000	31.0	29,450	29.5
C	16,357	33.1	15,452	30.9	24,639	24.6	23,089	23.1
Limestone - wet scrubbing	5,135	10.3	4,230	8.5	7,620	7.6	6,070	6.1

[a] 3.5% sulfur in coal.

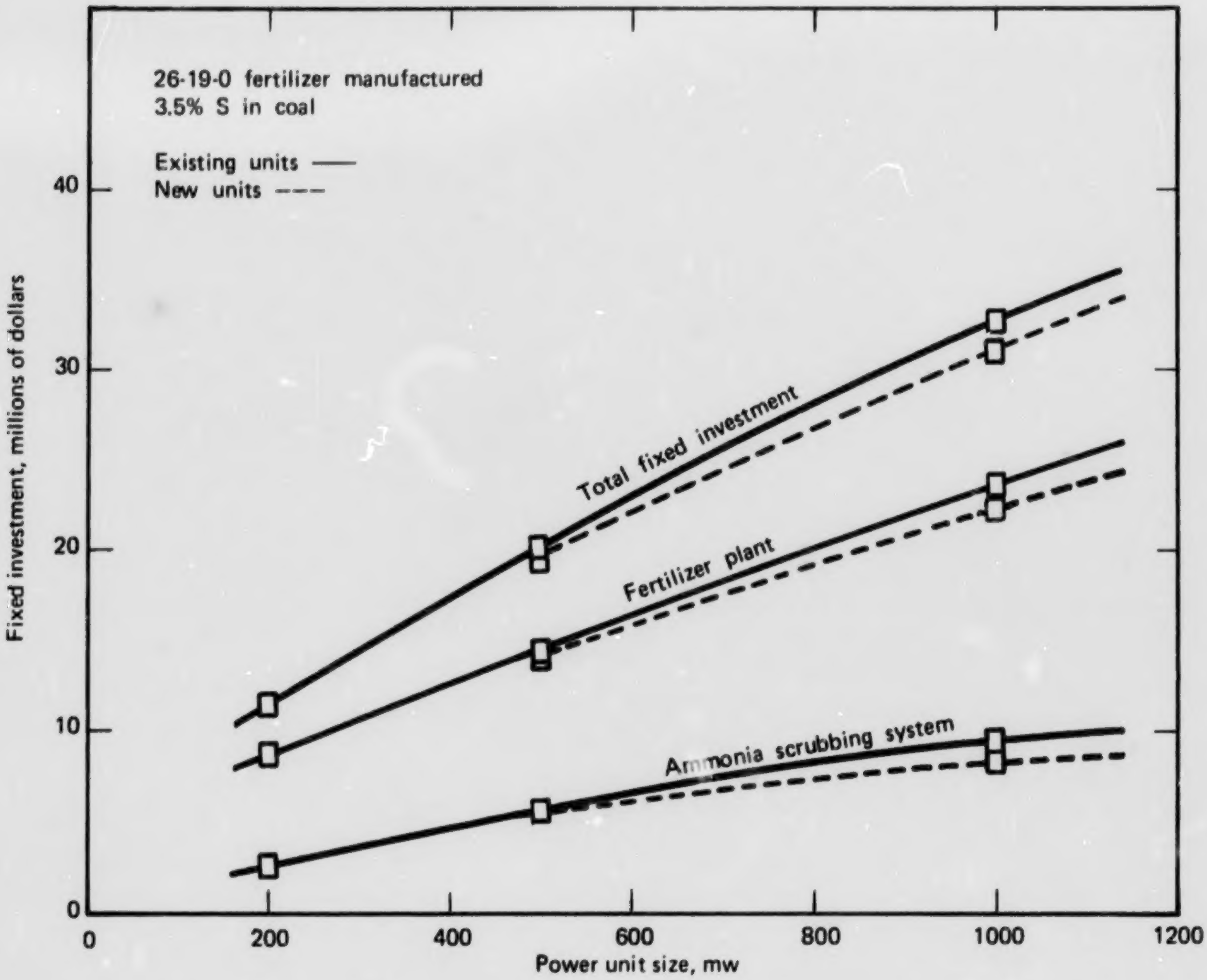


Figure 37. Effect of Power Unit Size on Ammonia Scrubbing - Fertilizer Plant Investment (process B)

1. Power industry financing
2. Chemical industry financing
3. Joint venture: power company portion
4. Joint venture: chemical company portion

Thus the total number of operating cost estimates was 84. These are given in tables B-22–B-105 in Appendix B.

For power industry financing (regulated utility-type economics), the usual practice was followed of including in the capital charges the regulated return on investment. A breakdown of the capital charges is given in table 17. The depreciation rate is based on the remaining life of the power plant after the pollution control process is installed and is a percentage of initial fixed investment. Interim replacements and insurance are also based on original fixed investment. However, because most regulatory commissions base the annual permissible return on investment on the remaining depreciation base (that portion of the original investment yet to be recovered or "written off"), a portion of the annual capital charge to be applied to the operating cost declines uniformly over the life of the investment. Annual return on equity, interest on debt, and income taxes are established in such a manner. In this study, the cost of money to the power industry is assumed to be 8% interest on borrowed money and 12% return on equity money to attract investors. Assuming a capital structure of 50% debt-50% equity, the overall cost of money under regulated economics comes to 10%. Federal income taxes are assumed to be 50% of gross income or equivalent to the return on equity. State income tax was assumed to be 80% of the national tax; the resulting figure is higher than for nonregulated industry but is about the nationwide average for power companies (32, 33).

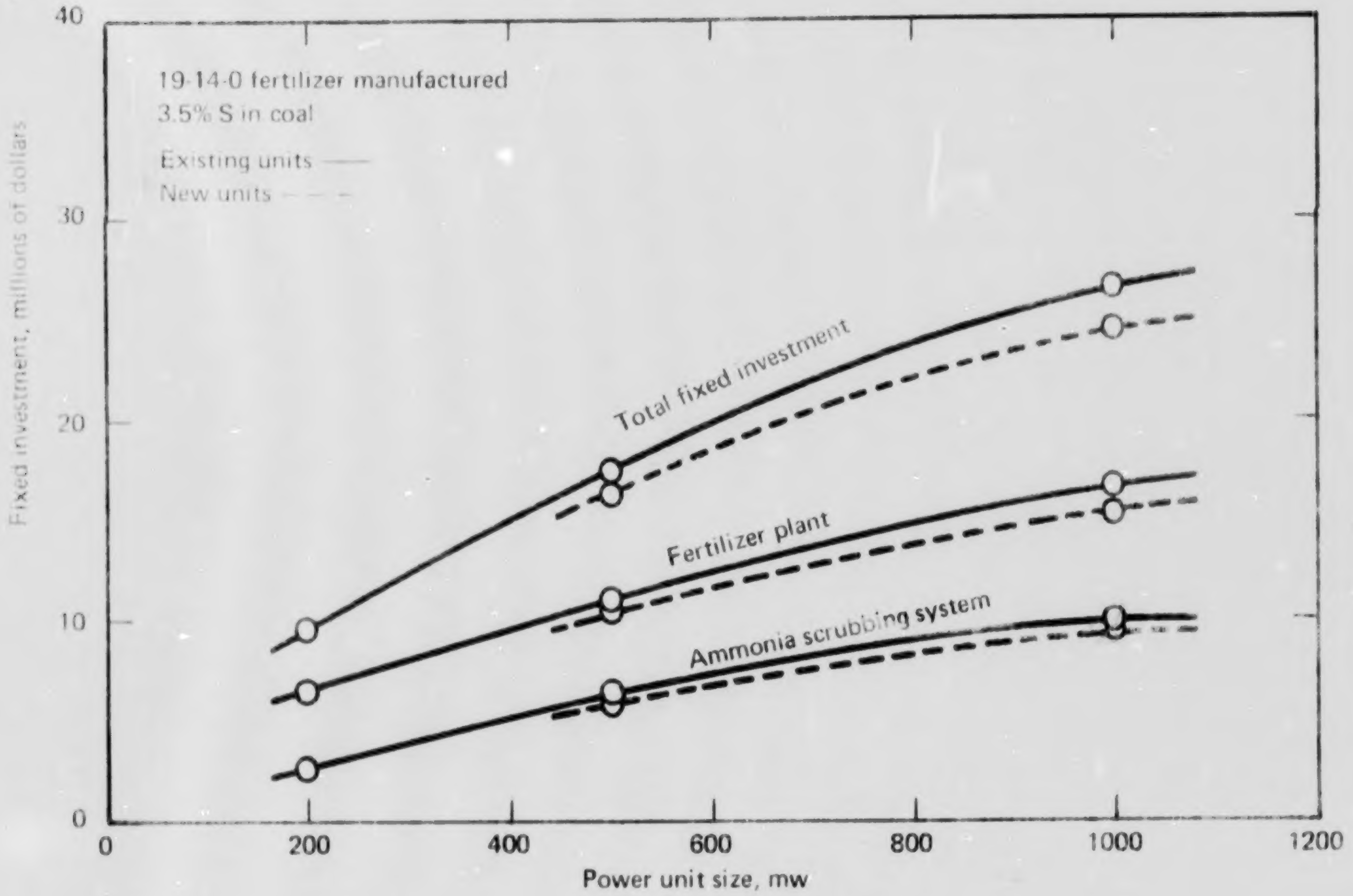


Figure 38. Effect of Power Unit Size on Ammonia Scrubbing - Fertilizer Plant Investment (process C)

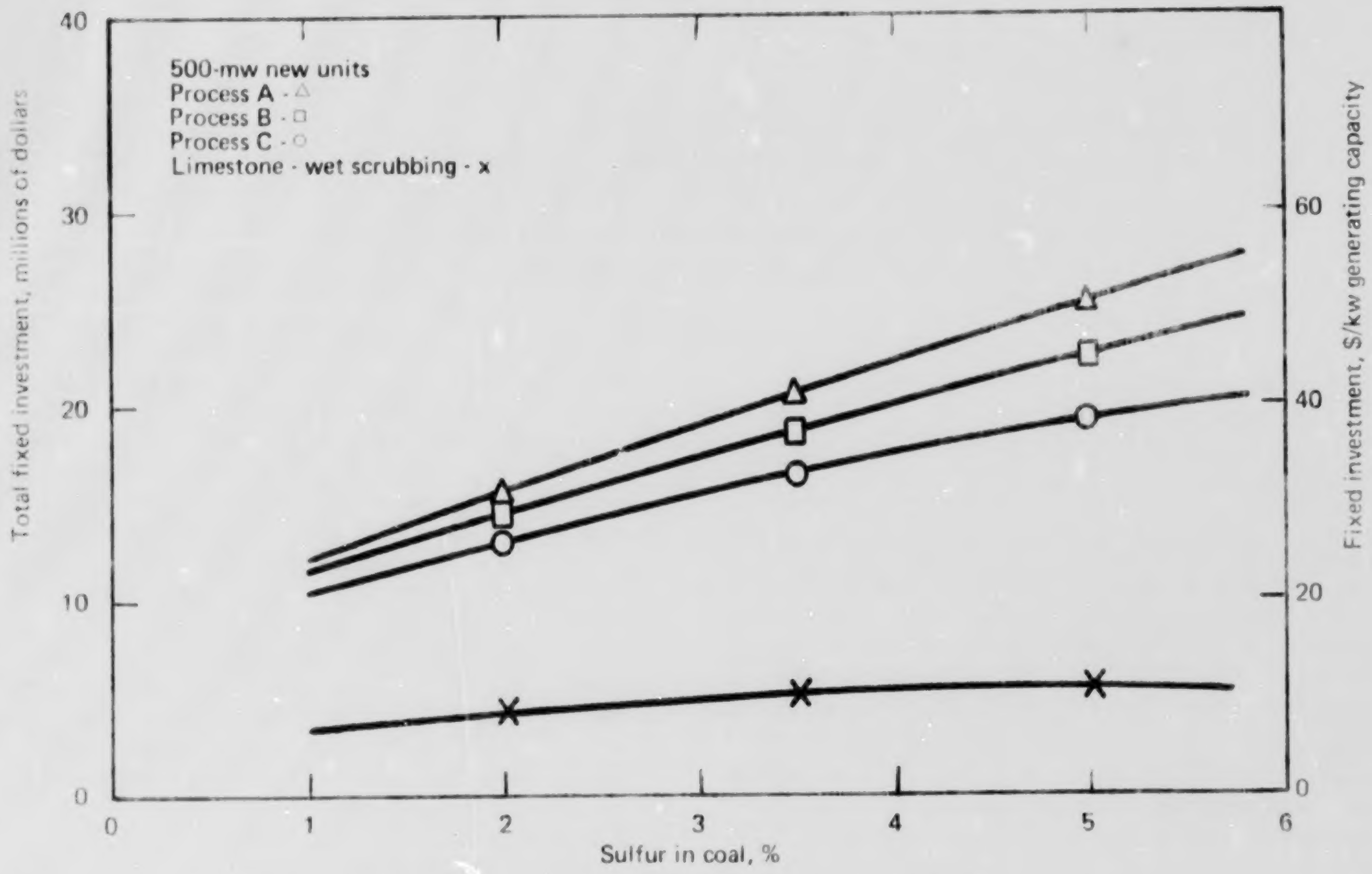


Figure 39. Effect of Sulfur Content of Coal on Total Fixed Investment

There are, of course, methods available to express the declining annual capital charge as a fixed annual percentage of original investment (for example, a single uniform series charge made up of sinking fund depreciation plus interest or capital recovery factor). On a present worth basis (recognizing the time value of money), the declining and the uniform annual capital charges are equivalent. An average annual charge was used for the operating cost estimates given in Appendix B; such a treatment is useful for direct comparisons. However, for the profitability estimates given later, the calculations were based on declining capital charges so that actual annual cash flows could be determined.

For chemical industry financing (unregulated economics), the only capital charges applied are depreciation, local taxes, and insurance. Hence the estimates are not directly comparable with those for power company financing because the latter include return on investment and income tax. Moreover, the depreciation rate for the unregulated economics basis (10%), which is commonly used in the industry, is much higher than for regulated economics (2.85%).

Using different bases for the estimates is confusing but seemed necessary as these are the approaches that are actually used in practice. The basic difficulty is that the regulated and unregulated bases cannot be compared in the usual way. The fairly well assured return on investment for the power company makes a low rate of depreciation acceptable, and return on investment can be logically included in production cost because it is a fixed charge passed on to the power customer. For the chemical company, however, a relatively high rate of depreciation is needed because of the risk factor and return on investment is a variable because it cannot be passed on to the customer as a cost item.

Table 17. Annual Capital Charges for Power Industry Financing - New Power Unit with 35-yr Life

	As percentage of original investment
Depreciation (based on a 35-yr life of a new power unit)	2.85
Interim replacements (equipment having less than 35-yr life)	0.75
Insurance	0.50
Total rate applied to original investment	4.10
	As percentage of outstanding depreciation base[a]
Cost of capital (capital structure assumed to be 50% debt and 50% equity)	
Bonds at 8% interest	4.00
Equity at 12% return to stockholder	6.00
Taxes	
Federal (50% of gross return or same as return on equity)	6.00
State (national average for states in relation to federal rates)	4.80
Total rate applied to depreciation base	20.80

[a]Original investment yet to be recovered or "written off."

Although the differing bases make comparisons between operating cost estimates infeasible, there is no difficulty in comparing economic promise, as will be seen later.

For joint ventures, such as operation of a scrubbing system by the power company and regeneration of the absorbent (with accompanying recovery of sulfur dioxide) by a chemical firm, the power portion was estimated on the regulated basis and the chemical company portion on the basis of unregulated economics.[3]

The delivered costs of raw materials, such as ammonia, phosphate rock, catalyst for production of nitric acid from ammonia, antifoam and product conditioner, are based on prices and freight rates considered to be likely over the next several yrs. For the larger plant sizes and higher sulfur content of the coal burned, price discounts and freight savings are assumed for some materials due to the increased volume and possibility of contractual agreements. Since the projections used in this study cover as many as 35 yrs and it is not possible to project raw material price changes for such a period, it is assumed that as the raw material prices change, so will the value of the product fertilizer.

Labor costs are based on current rates and are not escalated over the life of the project. Labor cost will certainly increase in the future but productivity increase in the past generally has kept up with wage increase. Lacking any better basis, it is assumed this relationship will continue.

The costs of utilities depend on quantity and source. The values used are fully allocated costs, as if purchased from an independent source with full capital charges included. For existing power plants, it was assumed that no excess steam, water, or electricity would be available and that new investment would be required; the new investment is not included in that shown for the process since the unit cost of the utility includes capital charges. For new power plants, it was assumed that provision would be made in the power plant design to furnish necessary utilities to the process, but the capital charge is included in the unit cost for this situation also.

---

[3] This assumes that the loaded absorbent would be passed "across the fence" to the chemical plant. However, the intermediate could also be collected from several power plants and processed in a large central plant to reduce processing cost. This concept has already been proposed by others and could have considerable potential; however, because the evaluation of such a venture could depend largely on the specific freight costs involved in shipping the intermediate to the fertilizer plant (and perhaps back again), this concept is considered outside the scope of generalized evaluation used in the present study.

Table 18. Lifetime Operating Costs for Ammonia Scrubbing Processes in New 500- and 1,000-mw Power Units[a]

	Total operating cost, $		Unit operating cost,[b] $/ton of coal burned		Unit operating cost,[b] $/ton of fertilizer	
	500 mw	1000 mw	500 mw	1000 mw	500 mw	1000 mw
Nonregulated Economics						
Process A	225,007,500	367,961,000	8.91	7.52	38.38	32.46
Process B	186,562,500	306,231,000	7.38	6.26	42.06	35.74
Process C	133,968,000	223,611,500	5.30	4.57	51.85	44.68
Cooperative Economics						
Process A	245,306,500	397,746,300	9.71	8.13	41.85	35.08
Process B	208,775,200	339,071,900	8.26	6.93	47.06	39.57
Process C	154,968,100	249,567,000	6.13	5.10	59.97	49.86
Regulated Economics						
Process A	302,344,400	491,743,400	11.97	10.05	51.58	43.38
Process B	258,478,200	417,215,500	10.23	8.53	58.27	48.69
Process C	193,135,400	313,022,200	7.64	6.40	74.74	62.54
Alternate limestone - wet scrubbing process	45,357,100	71,465,700	1.80	1.46	–	–

[a]Sulfur content of coal, 3.5%; yrs of operation, 35; operating factor (see text); no discounting of costs.
[b]Average over life of unit.

For all the operating cost estimates given in Appendix B, it is assumed that the fertilizer plant is sized to match the total potential output of the power plant and operates 7000 hr/yr. Thus the estimates apply only to the early yrs of power plant operation. Other estimates (not given in detail) were made to take into account the declining operating factor in the middle and later yrs of the power plant life (three additional estimates for each of the 84 combinations). Thus the costs over the entire plant operating life could be accumulated and the average production cost estimated. The resulting estimates are presented in table 18 for perspective and general interest only, as direct comparisons can be misleading.

An advantage is indicated for process C in cost/ton of coal but process A gives lower cost/ton of fertilizer. Both tonnage of fertilizer produced and price obtainable for the fertilizer must also be considered before any conclusions on the comparative economics can be made. The main conclusion from table 18 is that cost is far higher than for limestone - wet scrubbing and therefore a major return from sales is essential.

Comparisons between costs for early-life power plant operation (7000 hr/yr; tables B-22–B-105 in Appendix B) are given in figures 40-51. The effect of unit size for various combinations of other variables is given in figures 40-44 and the effect of sulfur content in figures 45 and 46. All these are given only to show the general effect of the variables; as for table 18, no conclusions can be drawn because of the varying effect of income items, which are applied later in the discussion of profitability.

Curves showing the effect of annual operating time on operating cost are given in figures 47, 48, and 49 for various size power units. Unit costs/ton of fertilizer under the same conditions are shown in figure 50 for process A. Increase in operating stream time, of course, effects a major reduction in unit operating cost.

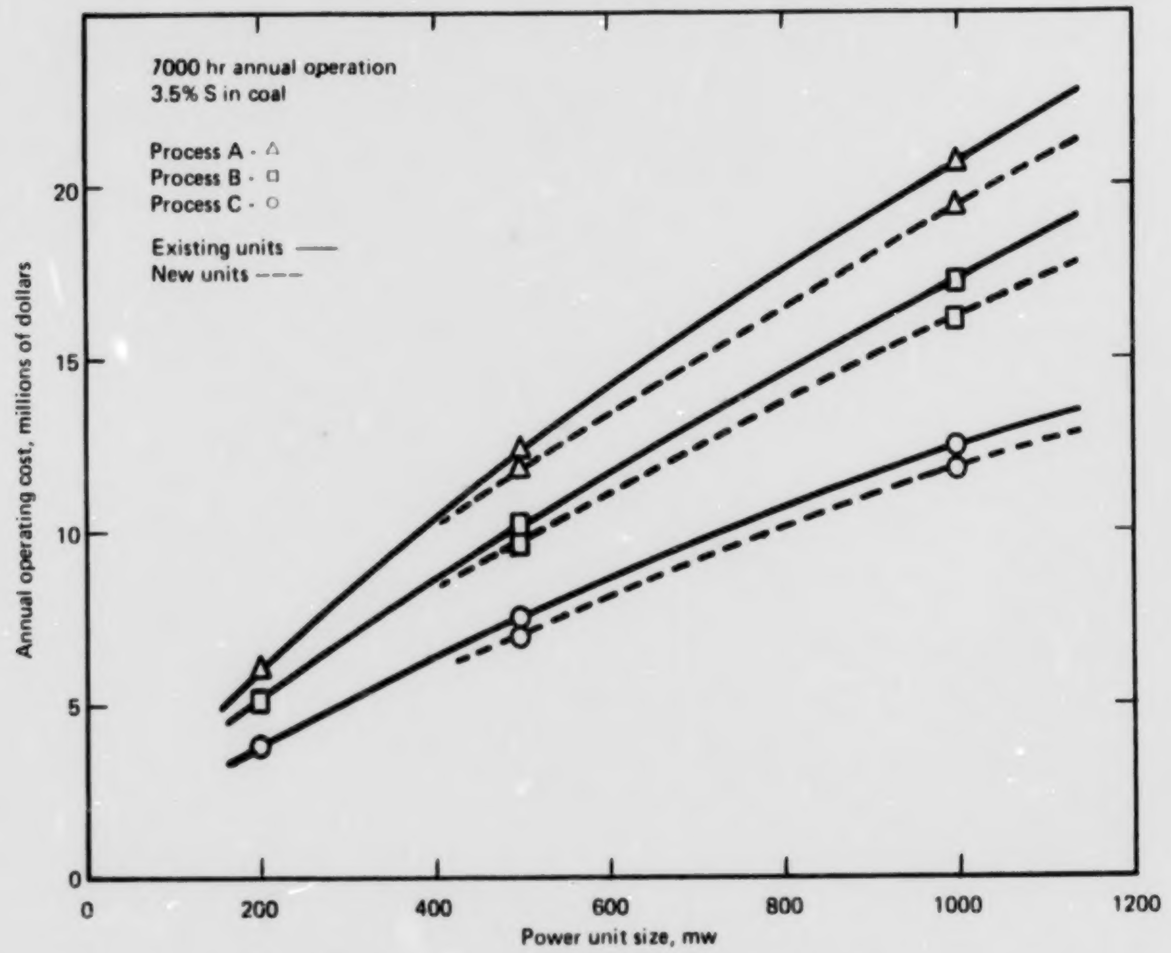


Figure 40. Effect of Power Unit Size on Annual Operating Cost Under Nonregulated Economics

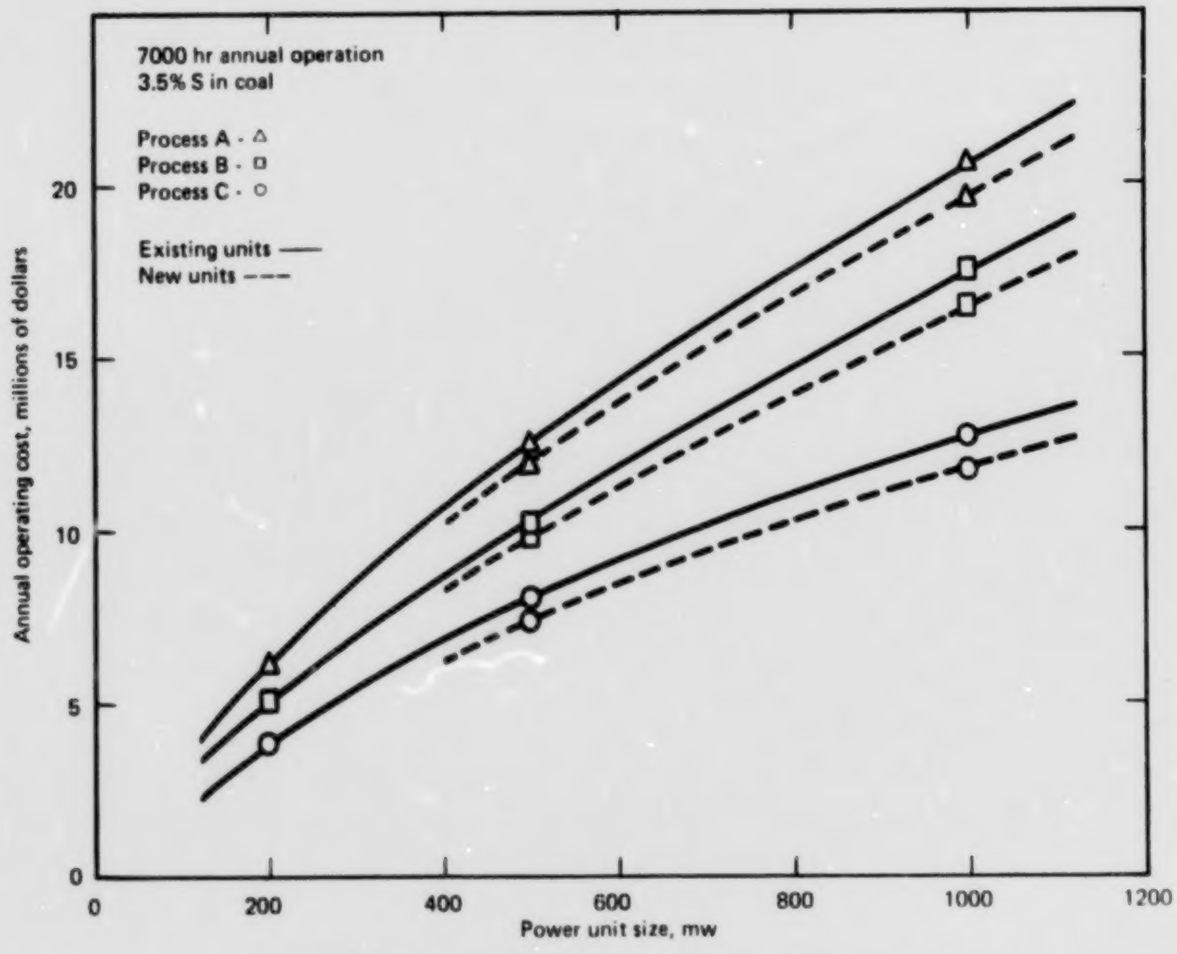


Figure 41. Effect of Power Unit Size on Annual Operating Cost Under Cooperative Economics

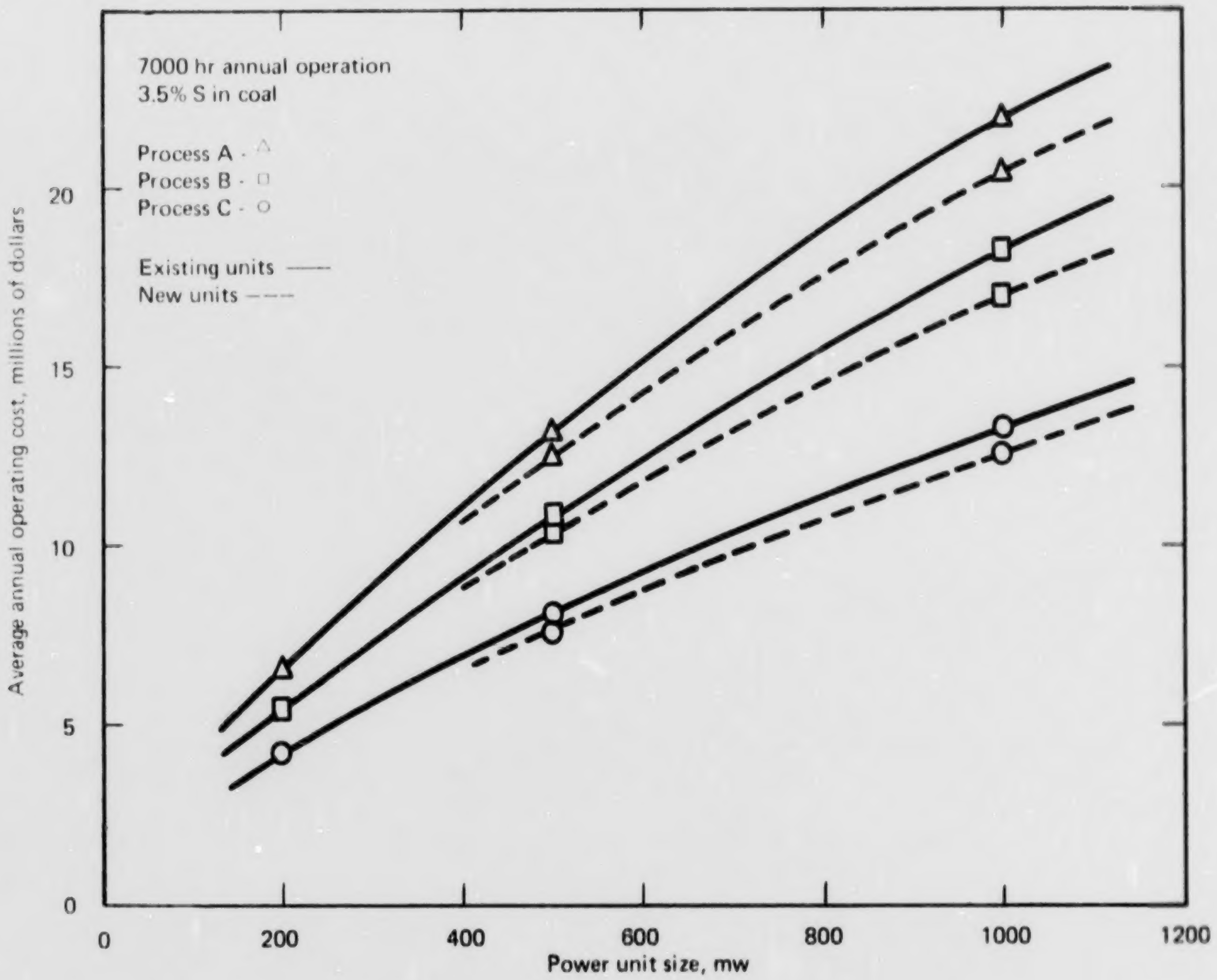


Figure 42. Effect of Power Unit Size on Average Annual Operating Cost Under Regulated Economics

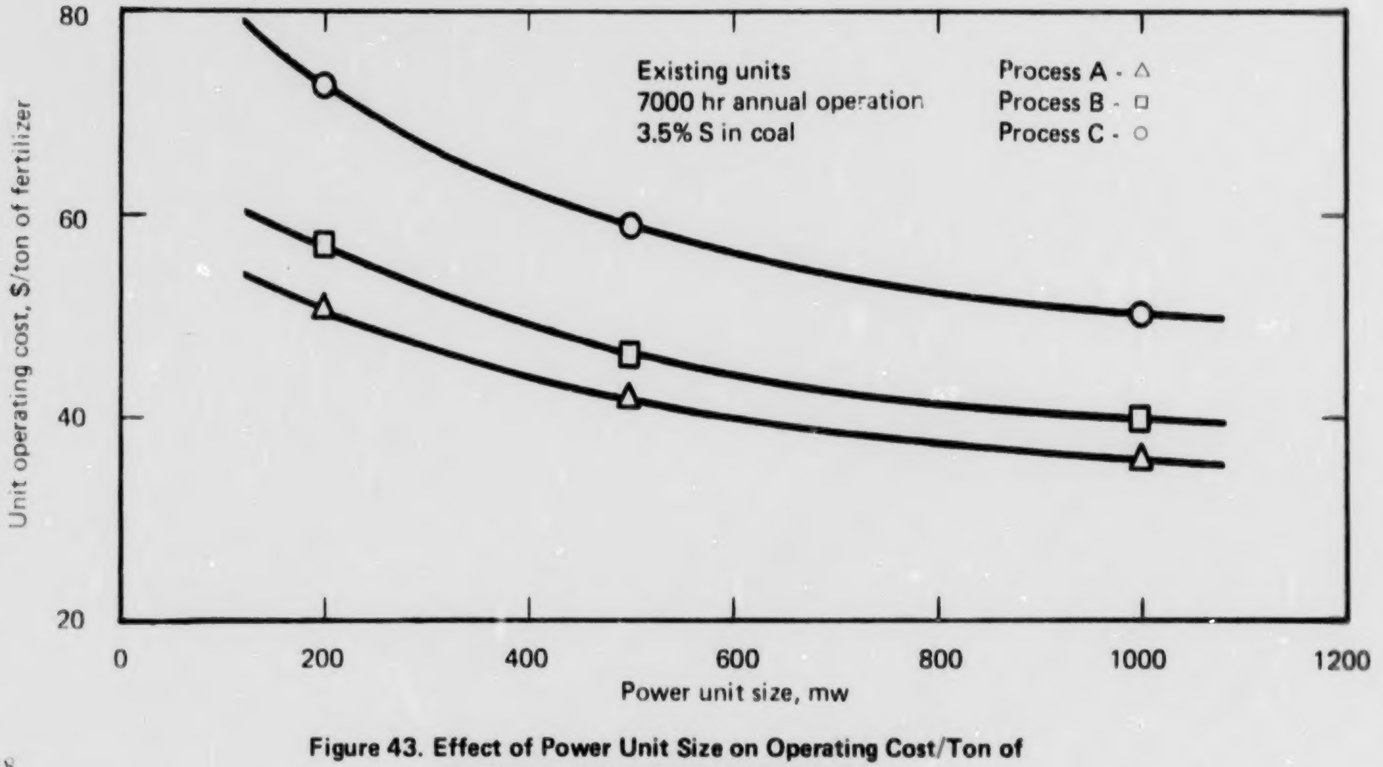


Figure 43. Effect of Power Unit Size on Operating Cost/Ton of Fertilizer Under Regulated Economics

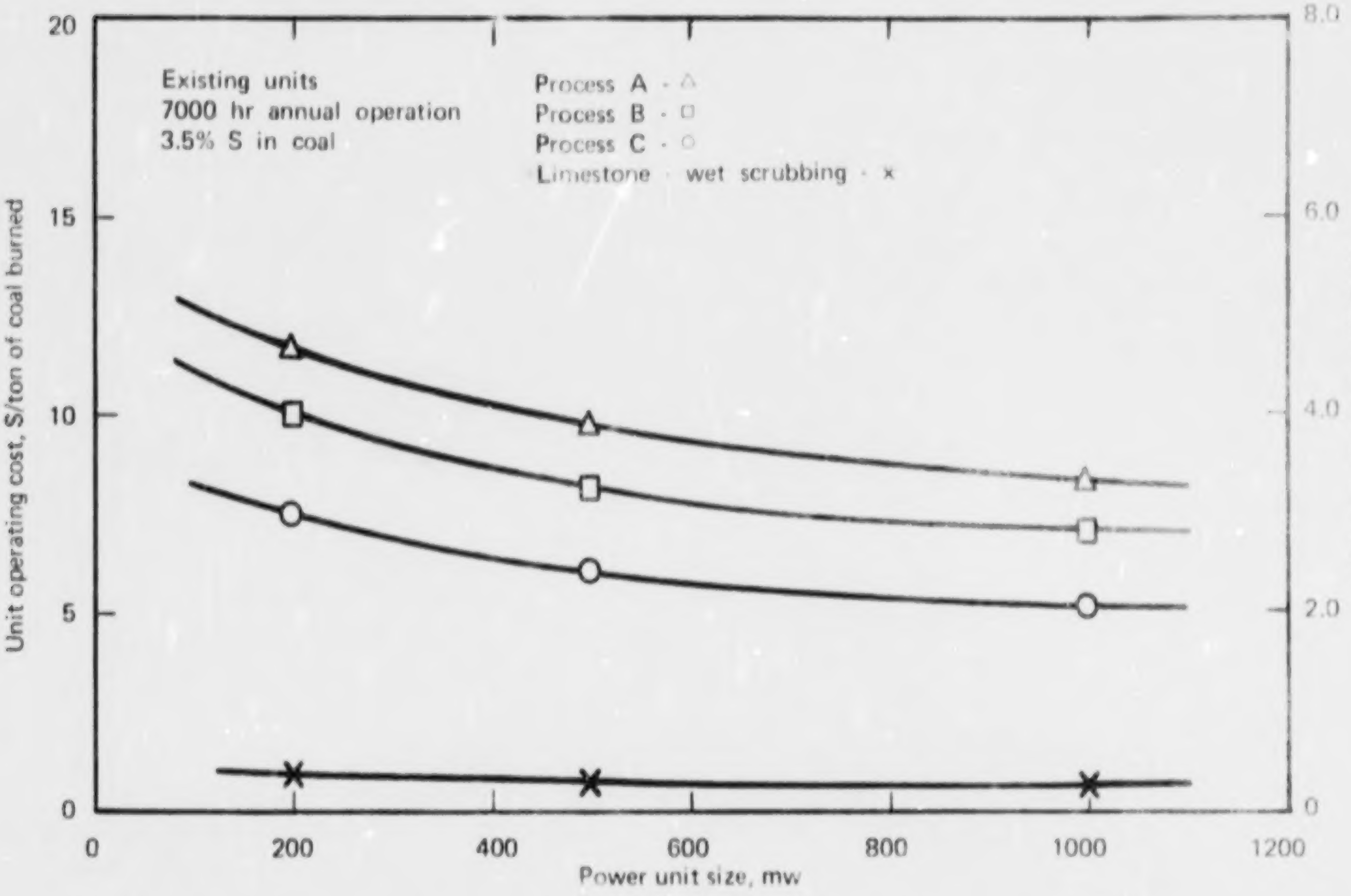


Figure 44. Effect of Power Unit Size on Operating Cost/Ton of Coal Under Regulated Economics

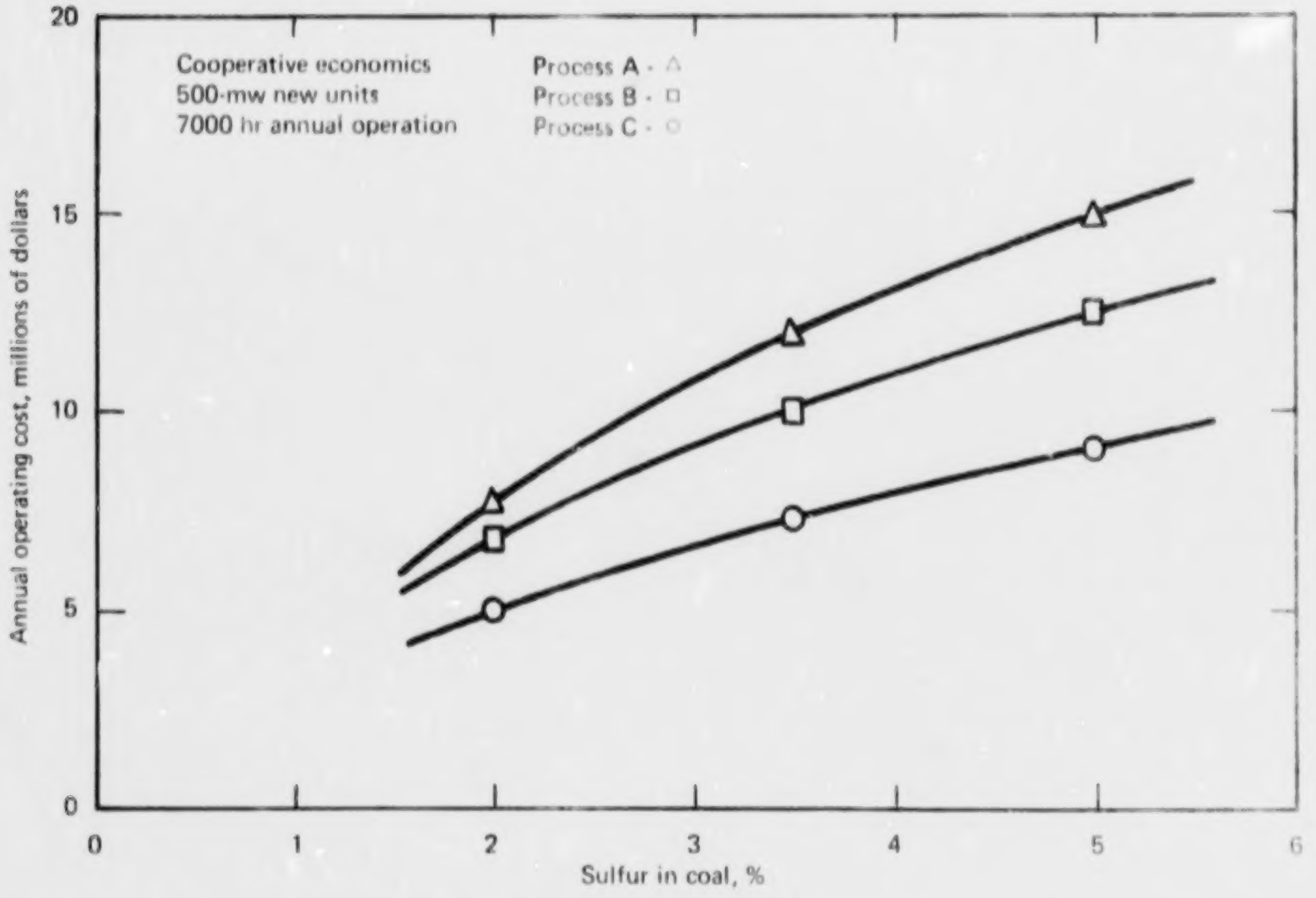


Figure 45. Effect of Sulfur Content of Coal on Annual Operating Cost Under Cooperative Economics

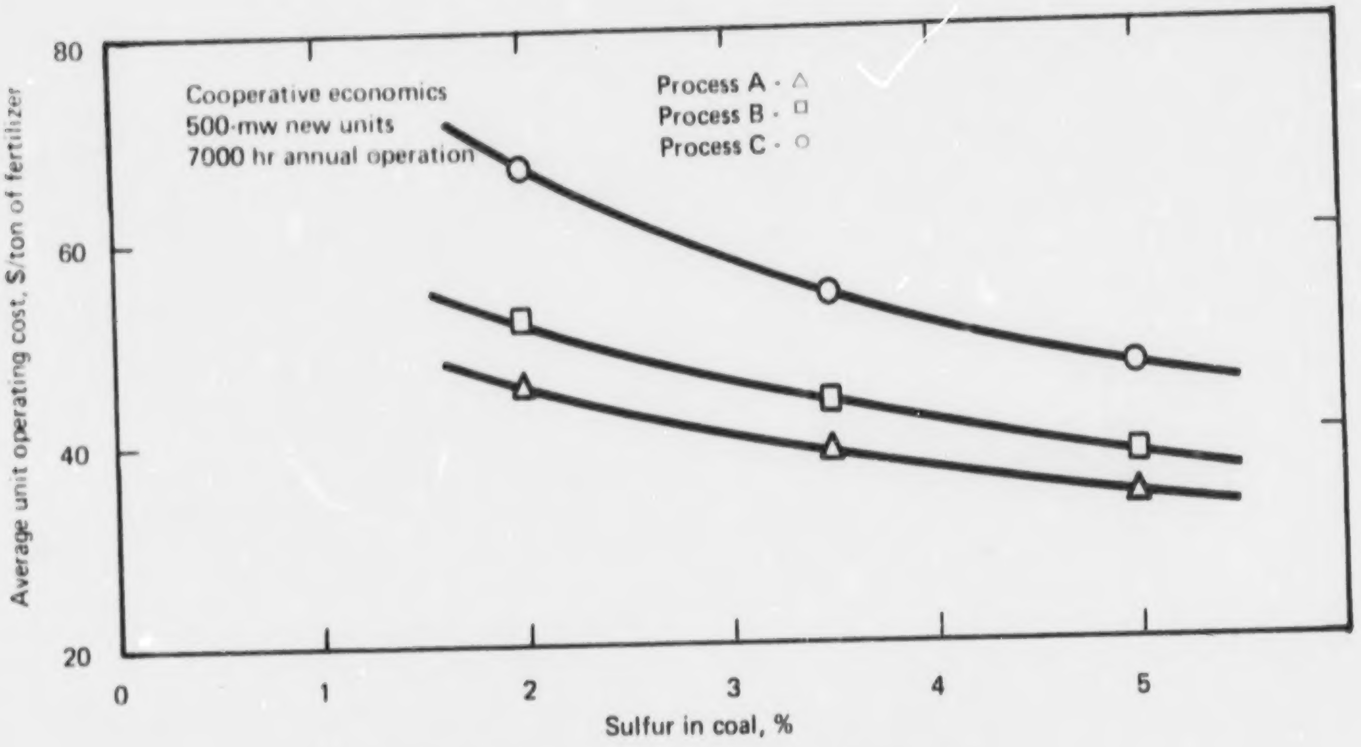


Figure 46. Effect of Sulfur Content of Coal on Unit Operating Cost Under Cooperative Economics

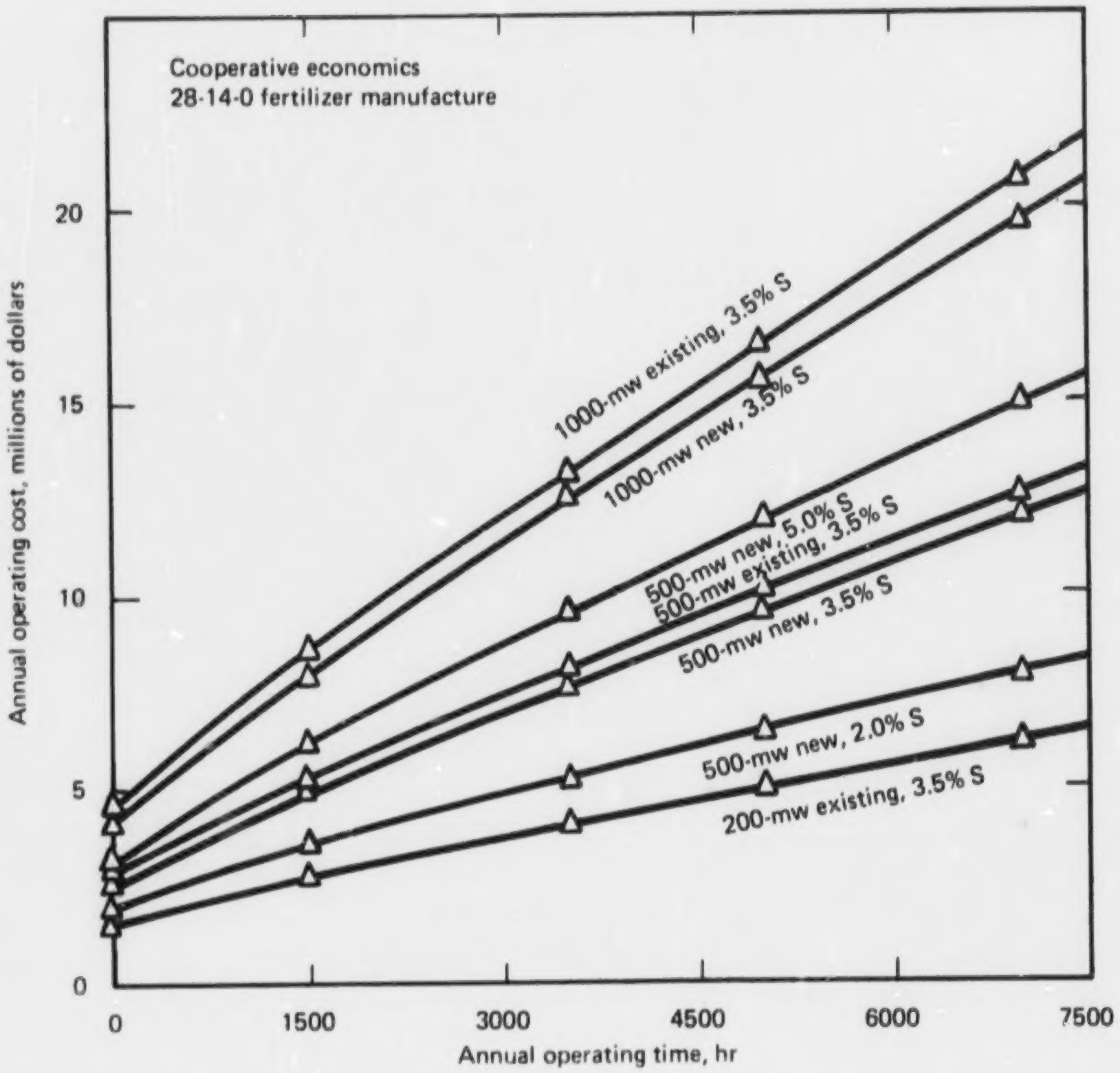


Figure 47. Effect of Process Operating Time on Annual Operating Cost (process A)

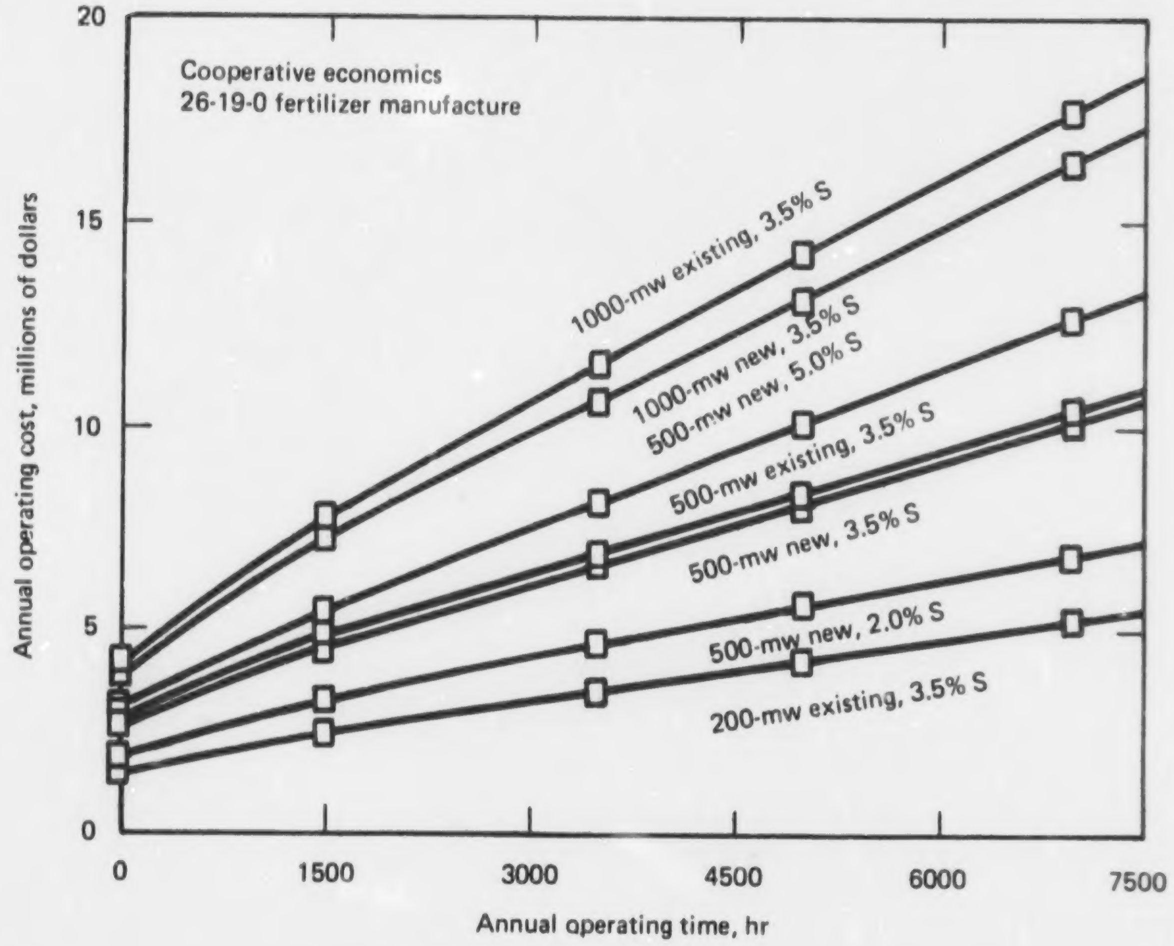


Figure 48. Effect of Process Operating Time on Annual Operating Cost (process B)

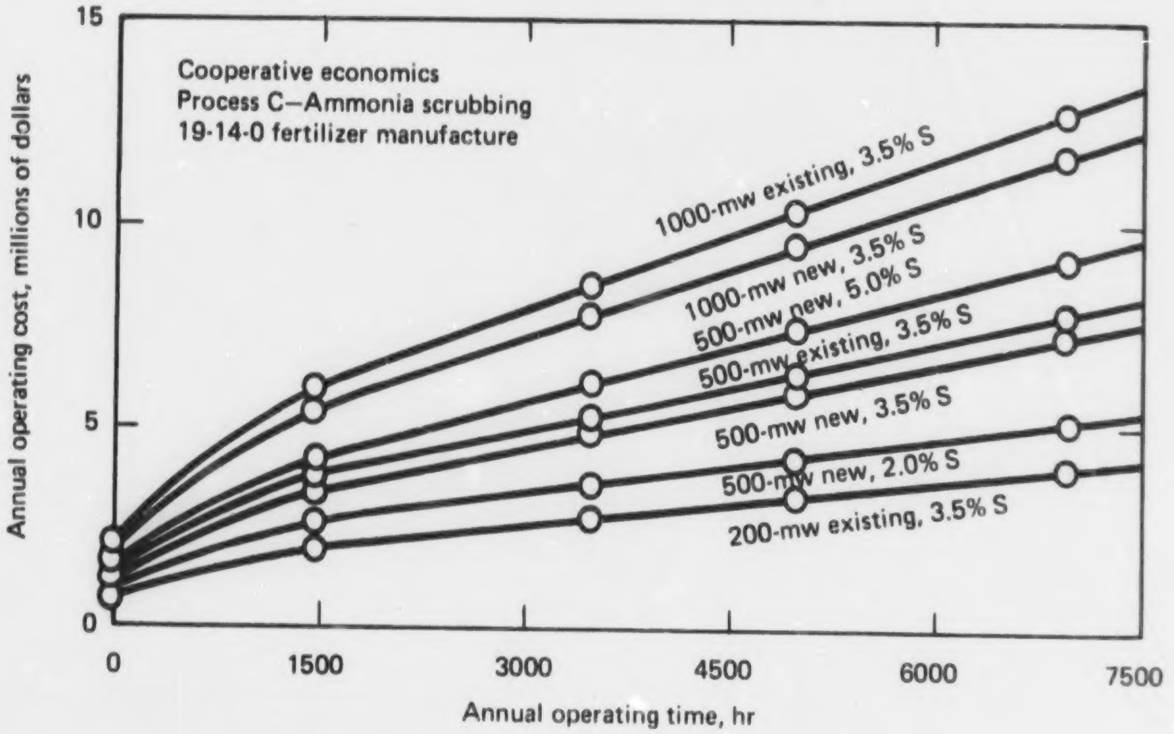


Figure 49. Effect of Process Operating Time on Annual Operating Cost (process C)

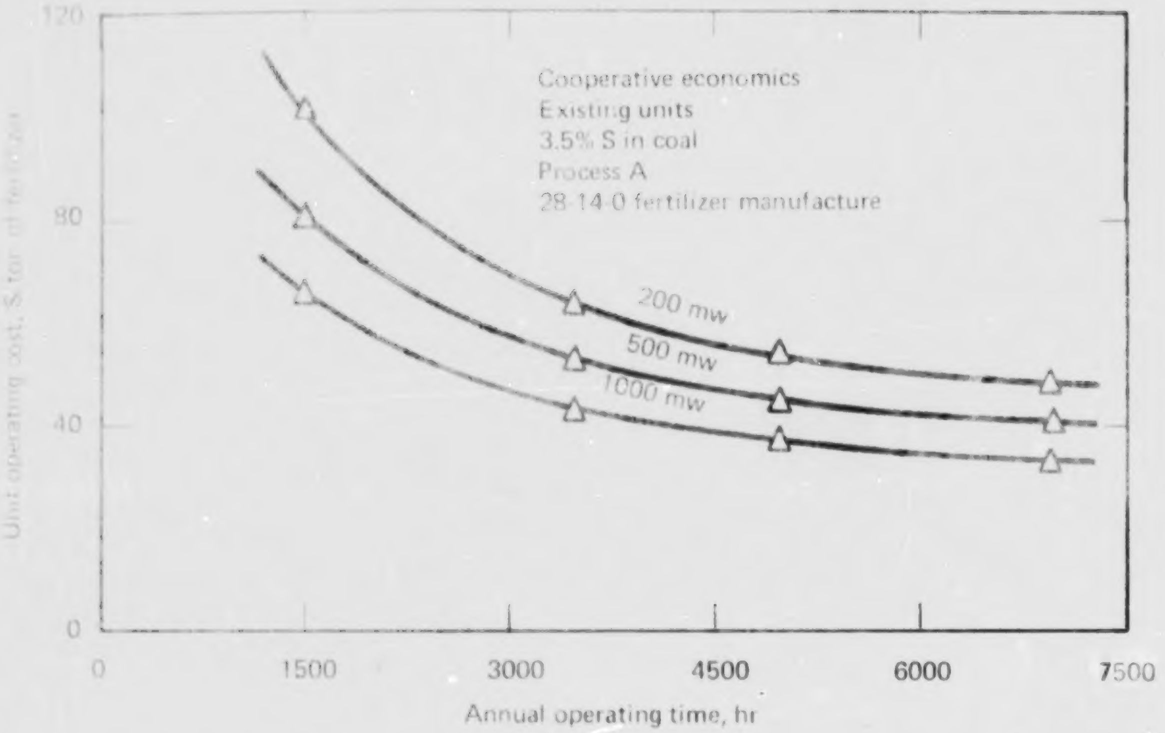


Figure 50. Effect of Process Operating Time on Unit Operating Cost

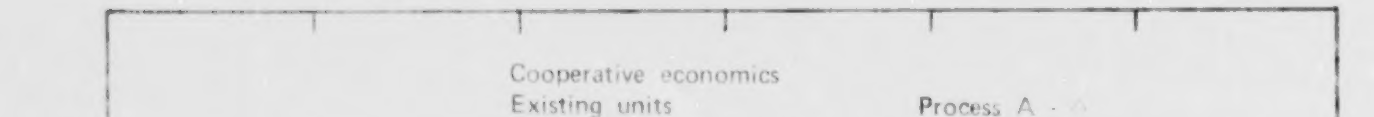


Figure 51. Effect of Credit for Air Pollution Control on Unit Operating Cost

PROFITABILITY AND ECONOMIC POTENTIAL

Having established investment and operating costs, the next step is to determine profitability (plus or minus) of the various process combinations and to relate this to economic attractiveness as compared with other ways of solving the pollution problem. This is a much more difficult task as it requires estimation of net income from product sale, and income can vary over a wide range depending on several variables that cannot be evaluated accurately.

Net income depends not only on sales price but also on production volume (which varies between the processes considered), sales cost (which will likely be higher for a power company than a chemical company), and shipping cost (which varies with size of the sales area needed to move the product). Much of this depends on the market potential for the product; therefore a market study was conducted as the first step in determining profitability.

MARKET STUDY

The end products of the processes considered differ mainly in the ratio of the two plant nutrients involved—nitrogen (N) and available phosphoric acid (P_2O_5). In the order of decreasing nitrogen to phosphate ratio, these products are 21-0-0, 28-14-0, 26-19-0, and 19-14-0 (% N-% P_2O_5-% K_2O). The fact that the plant nutrient ratios and contents differ complicates determination of relative market price. Moreover, because of the process complexities described earlier, the tonnages of the various products differ considerably; for a 500-mw plant burning coal containing 3.5% sulfur, 156,000; 304,000; 230,000; and 134,000 tons of the respective grades above would be produced each yr. Thus, the size of the market area required varies with each and affects transportation costs. For example, the total amount of nitrogen produced is 3.5 times as great for 28-14-0 as for 19-14-0. As a result, it is estimated that the market area would be increased to the extent that average shipping cost for 28-14-0 would be $7.00/ton of nutrient as compared with $4.30 for 19-14-0.

Although transportation costs are the major source of calculable variation, estimation of nutrient sales price is the first order of business. An understanding of the basis for pricing in the current market is necessary.

Fertilizer Industry Logistics

Present Market— Almost all fertilizers are produced from some combination of four basic *raw materials*—ammonia, phosphate rock, sulfuric acid, and potassium chloride. Although significant quantities of ammonia and sulfuric acid are produced as industrial byproducts, the primary sources of these materials are natural gas and elemental sulfur, respectively. The basic logistical problems facing the U. S. fertilizer industry stem from the fact that commercially minable sources of phosphate rock, potassium chloride, sulfur, and natural gas do not occur at the same location and do not all occur near major end-use markets. Problems of collecting the basic raw materials, processing them into the types of products needed by farmers, and supplying them at the time of need are complex.

The major source of phosphate rock is near Tampa, Florida. The major source of sulfur is near the Gulf Coast of Louisiana. These two materials are used to produce phosphoric acid mainly along the gulf coast, in Florida, and northern Illinois (figure 52). Many of the northern plants use byproduct sulfuric acid. The phosphoric acid producers supply the major portion of the phosphate fertilizer markets by combining the acid with phosphate rock to produce triple superphosphate (0-46-0) or with ammonia to produce diammonium phosphate (18-46-0). The distribution of the phosphates to domestic markets is significantly influenced by barge transportation along the inland waterway (figure 53); this alternative compels rail rates which are much lower than they ordinarily would be. An example of comparative rates is shown in table 19.

Ammonia is produced from natural gas in every major consuming region. Recent technological developments in large-scale production have caused a shift in location for new production capacity to the Gulf Coast area where low-cost gas is available (figure 54). Distribution of this production to the midsection of the country is facilitated by pipeline shipment (figure 55).

The present study does not involve the use of potassium chloride because the products contain only nitrogen and phosphate. As a matter of interest, potassium chloride is

Table 19. Phosphate Rock Transportation Cost Via Rail and Barge From Tampa, Florida[a]

Method of delivery	Minimum quantity, tons/yr	Muscle Shoals	East St. Louis	Chicago
Barge		5.28	4.78	5.28
Rail	140,000	5.75	6.50	6.95
	120,000	5.95	6.70	7.15
	100,000	6.15	6.90	7.35
	80,000	6.35	7.10	7.55
	60,000	6.55	7.30	7.75
	40,000	6.75	7.50	7.95
	—	7.65	8.40	8.85

[a] Rail rates reflect TVA Section 22 negotiations.

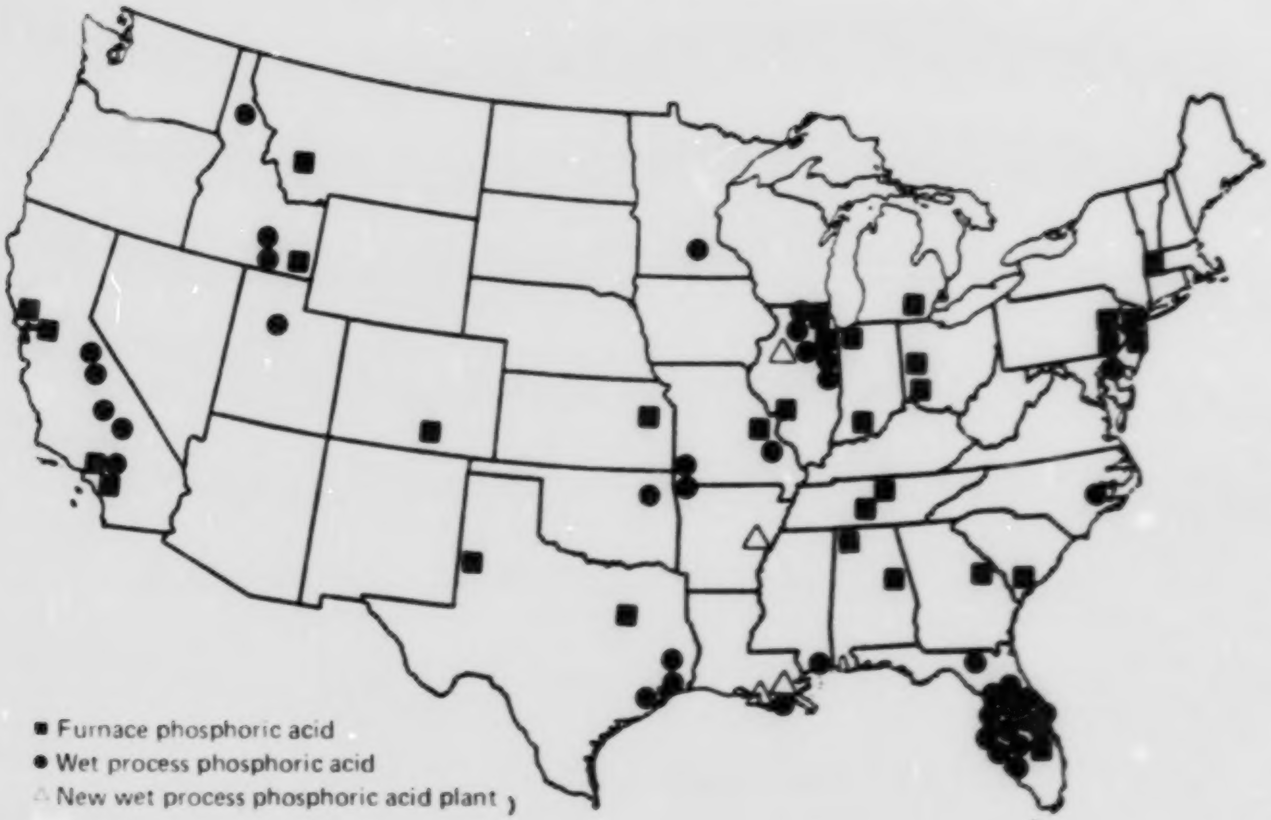

■ Furnace phosphoric acid
● Wet process phosphoric acid
△ New wet process phosphoric acid plant

Figure 52. Phosphoric Acid Plant Locations

mined in New Mexico and in Canada and shipped to the point of use, normally by rail.

The *fertilizer production* pattern is somewhat complex. Some plant nutrient requirements are met by direct application of materials sometimes considered as intermediates, such as ammonia, ammonium nitrate, and superphosphate. However, most fertilizers are supplied as mixes or blends by a local producer who purchases the nitrogen, phosphate, and potash materials and proportions them to meet required ratios of nutrients. The blended materials are normally transported only a short distance to the farmer. This system, generally called bulk blending, prevails throughout the Midwest (figure 56). In 1968, there were 1537 bulk blenders in the states of Indiana, Illinois, and Iowa, or approximately one for every 100 sq miles. If the area were uniform, each blender would serve a circular area about 6 miles in radius. This indicates the large number of blending plants serving small, local markets.

Another system, chemical mixing, is also widely used. One version is mixing phosphate rock with local supplies of sulfuric acid to produce normal superphosphate (0-20-0), which is then mixed with nitrogen solutions and potassium chloride to produce granular mixed fertilizer of the desired ratio. Triple superphosphate (0-46-0) may also be included in the mix. Still another system is production of ammonium phosphate from phosphoric acid and ammonia with other materials such as potassium chloride added, if required, during the manufacturing operation.

Fertilizer consumption in four major regions is shown in figure 57. The historical consumption of nitrogen is shown in figure 58. The North Central region has shown by far the greatest growth and also has a high consumption density. There are other regions with high levels of consumption but the North Central is the only one that extends over a large area. Therefore, the Midwest was chosen as the primary marketing area for this study and fertilizer use was evaluated in detail.

The states of Iowa, Illinois, and Indiana are considered to be representative of the general use pattern in the region. The nitrogen market is most critical because the recovery products will be used mainly to supply nitrogen. The quantity of nitrogen consumed in these three states by type of product is shown in table 20. Consumption is reported as that supplied by direct application materials and that supplied by mixtures. Bulk blend consumption in Illinois is shown in table 21; consumption in Iowa and Indiana was assumed to be in the same proportion to the total as in Illinois. Based on data in table 20, nitrogen consumption densities were calculated and are summarized in table 22. The three-state average should be considered a statistical

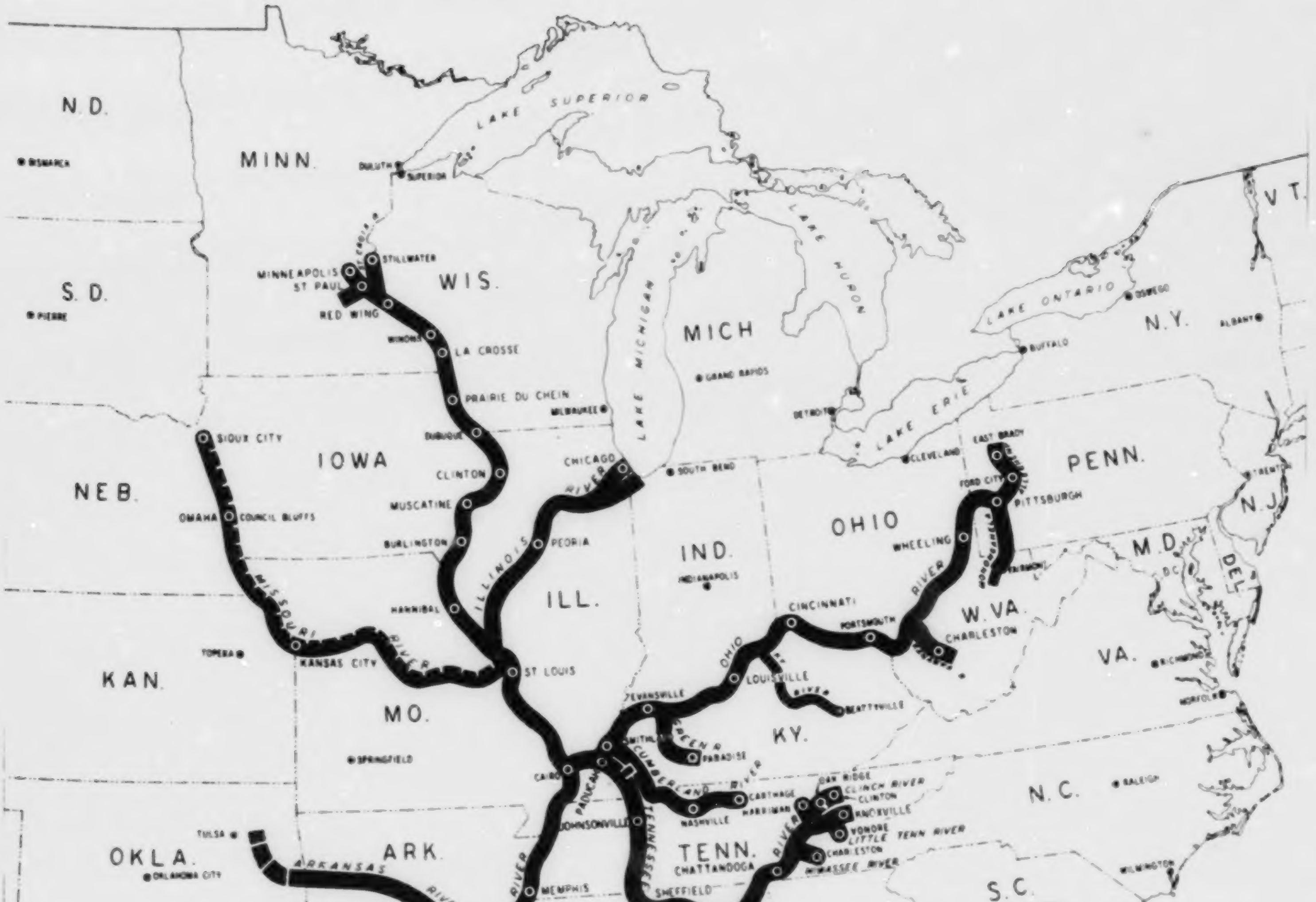

LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
LAKE ERIE
LAKE ONTARIO
N.D.
S.D.
MINN.
WIS.
MICH
IOWA
NEB.
KAN.
MO.
ILL.
IND.
OHIO
PENN.
N.Y.
VT.
N.J.
M.D.
DEL.
W.VA.
VA.
KY.
TENN.
N.C.
S.C.
GA.
ALA.
MISS.
ARK.
OKLA.
TEXAS
LA.
FLA.
MISSOURI RIVER
ILLINOIS RIVER
MISSISSIPPI RIVER
OHIO RIVER
GREEN R.
CUMBERLAND RIVER
TENNESSEE RIVER
CLINCH RIVER
LITTLE TENN RIVER
HIWASSEE RIVER
ARKANSAS RIVER
OUACHITA RIVER
WARRIOR RIVER
ALABAMA RIVER
CHATTAHOOCHEE R.
FLINT R.
MINNEAPOLIS
ST PAUL
STILLWATER
RED WING
WINONA
LA CROSSE
PRAIRIE DU CHEIN
DUBUQUE
CLINTON
MUSCATINE
BURLINGTON
HANNIBAL
ST LOUIS
CHICAGO
PEORIA
SIOUX CITY
OMAHA
COUNCIL BLUFFS
KANSAS CITY
CINCINNATI
PORTSMOUTH
LOUISVILLE
EVANSVILLE
PITTSBURGH
WHEELING
CHARLESTON
CAIRO
PADUCAH
NASHVILLE
CARTHAGE
KNOXVILLE
CHATTANOOGA
SHEFFIELD
DECATUR
GUNTERSVILLE
MEMPHIS
HELENA
LITTLE ROCK
GREENVILLE
VICKSBURG
NATCHEZ
BATON ROUGE
NEW ORLEANS
MORGAN CITY
LAKE CHARLES
BEAUMONT
PORT ARTHUR
HOUSTON
GALVESTON
CORPUS CHRISTI
BROWNSVILLE
MOBILE
PENSACOLA
PANAMA CITY
APALACHICOLA
COLUMBUS
BAINBRIDGE
TUSCALOOSA
DEMOPOLIS
MONTGOMERY
CHANNEL MILEAGE
7600 MILES 9 FT. OR MORE
1800 MILES 6-9 FT.
LEGEND
9 FT. DEPTH OR MORE
6 FT. TO 9 FT. DEPTH
UNDER CONSTRUCTION

Figure 53. Central U. S. Inland Waterway System

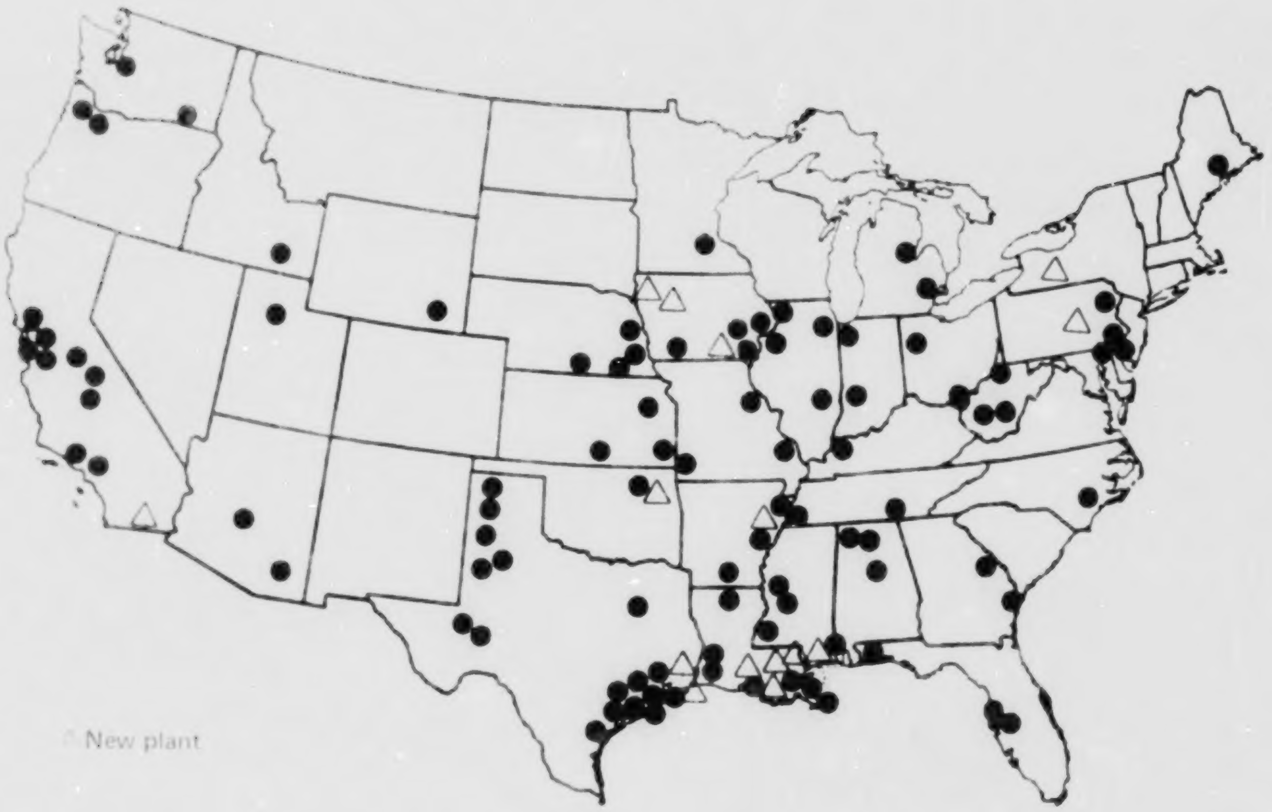


Figure 54. Ammonia Plant Locations

Table 20. Nitrogen Market Profile in the Midwest, 1967 (Tons Nitrogen) (86)

	Iowa	Illinois	Indiana
Land area (sq miles)	56,032	55,930	36,185
Direct application materials	451,682	464,239	234,926
Anhydrous ammonia	331,619	282,970	117,978
Aqua ammonia	28,187	38,037	10,311
Nitrogen solutions	51,646	90,681	79,535
Ammonium nitrate	35,205	42,400	16,370
Ammonium sulfate	50[illegible]	4,905	763
Urea	3,298	4,346	8,917
Phosphate materials	1,227	900	1,052
Commercial mixtures	(69,855)	102,762	(73,943)
Ratio (1-4-X)	20,133	21,003	26,115
Ratio (1-1-1)	732	11,842	15,919
18-46-0	23,327	13,776	18,890
Other	(25,663)	56,141	(13,019)
Custom mixtures	(21,834)	32,120	(23,112)
Total mixtures	91,689	134,882	97,055
Total nitrogen	543,47[illegible]	599,954	332,125

Source: Consumption of Commercial Fertilizers in the U. S., 1967 USDA S_pC_r7 (5-68). Figures in parenthesis are estimated in proportion to Illinois.

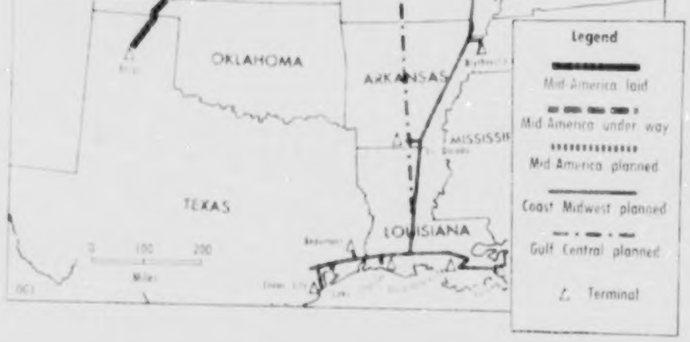

WISCONSIN
MICHIGAN
NEBRASKA
IOWA
ILLINOIS
INDIANA
KANSAS
MISSOURI
KENTUCKY
OKLAHOMA
ARKANSAS
MISSISSIPPI
TEXAS
LOUISIANA
0 100 200
Miles
Legend
Mid-America laid
Mid-America under way
Mid-America planned
Coast Midwest planned
Gulf Central planned
Terminal

Figure 55. Major Ammonia Pipelines

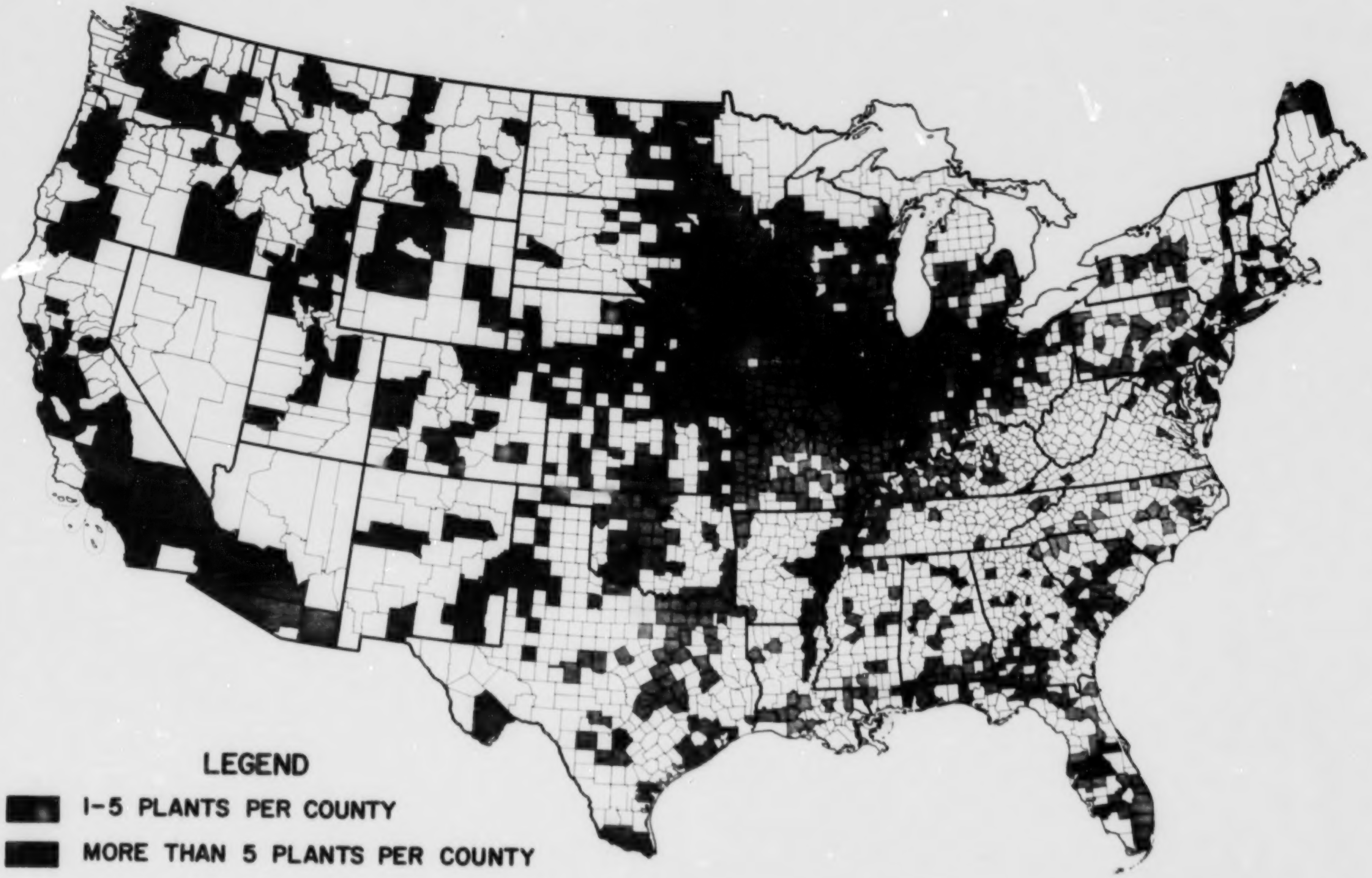

LEGEND
I-5 PLANTS PER COUNTY
MORE THAN 5 PLANTS PER COUNTY

Figure 56. Bulk Blend Fertilizer Plants by Counties (1968)

Table 21. Materials Sold as Custom Mixtures in Illinois, 1966-1967 (Tons) (86)

	Quantity of Material	N	Estimated P_2O_5	K_2O
Nitrogen solutions	9,374	3,140		
Ammonium nitrate	20,616	6,906		
Urea	2,457	1,106		
Ammonium sulfate	3,781	794		
Superphosphate under 22%	3,224		645	
Superphosphate over 22%	35,953		16,538	
18-46-0	91,758	16,5[illegible]	42,209	
11-48-0	33,102	3,641	15,889	
Muriate of potash	82,971			49,783
Miscellaneous	194	17	34	34
Total	283,430	32,120	75,315	49,817

Source: Consumption of Commercial Fertilizers in the United States, 1967 USDA $S_pC_{\pi}7$ (5-68), page 5.

Table 22. Fertilizer Materials Consumption and Average Consumption Density for the Iowa-Illinois-Indiana Area (Tons Nitrogen)

Item	Area totals	Average consumption density (tons/sq mi)	
Land area (sq mi)	148,147		
Direct application materials	1,150,847	7.77	
Anhydrous ammonia	732,567	4.95	6.96
Aqua ammonia	76,535	.52	
Nitrogen solutions	221,862	1.50	
Ammonium nitrate	93,975	.63	0.81
Ammonium sulfate	6,168	.04	
Urea	16,561	.11	
Phosphate materials	3,179	.02	
Commercial mixtures	246,560	1.66	
Ratio (1-4-X)	67,251	.45	
Ratio (1-1-1)	28,493	.19	
18-46-0	55,993	.38	
Other	94,823	.64	
Custom mixtures	77,066	.52	
Total mixture	323,626	2.18	
Total nitrogen	1,475,550	9.95	

estimate of point consumption density. Through use of the point estimate, the density patterns shown in figure 57 can be used to extrapolate to other areas in the North-Central region.

The potential for movement of recovery products in international markets was considered. Many countries now have or soon will have local ammonia production capability based on natural resources or imported petroleum products. With the inclination to protect local industries with import tariffs and quotas, it would appear risky to base an investment decision on significant penetration of foreign nitrogen markets. Moreover, even the current export market, mainly ammonium sulfate, is dwindling and has left large supplies of byproduct ammonium sulfate looking for new markets.

The international phosphate markets are somewhat different since local supplies of phosphate rock and sulfur are limited. Trade in phosphate fertilizers is significant and should continue to grow.

Substitution of Recovery Products—The most significant possibility for ***raw material substitution*** is use of sulfur-containing products recovered from a power plant instead of mined sulfur. The location of major thermal power plants is shown in figure 59. By using such local sulfur, cost of recovery might be partially offset by reduced transportation costs. Power plants are normally located near large streams because of cooling water requirements so that low-cost barge shipments or rail shipments at water-compelled rates could be negotiated for phosphate rock requirements.

Although not a recovery product, partial substitution of nitric acid for sulfuric acid to digest the phosphate rock may also be an important raw material factor. Nitric acid might be available at relatively low price from local producers who face competition from direct application of ammonia delivered by pipeline. Economics may also favor production of nitric acid since the large quantities of ammonia required in the scrubbing operation may give low ammonia cost.

The recovery products are also well suited for substitution in ***bulk blending***. This is fortunate since much of the output from recovery plants must of necessity move through the bulk blending outlets.

In addition to use in bulk blends, substitution of recovery products in the *direct application* market is another potential outlet. Seventy percent of all the nitrogen applied is supplied as ammonia and nitrogen solutions, the lowest cost sources. It is assumed that recovery products will not compete with this use. Use of solid nitrogen products for direct application is practiced on some of the smaller farms because of the large investment required for liquid application equipment. Recovery products can be substituted in this use although they are at a disadvantage because of the dual nutrient content. Nitrogen, which readily leaches from the soil, is often applied after the crop is up while phosphates are applied prior to planting because they are more stable and represent a long-term investment in soil fertility. The value of nitrogen in a multi-nutrient material applied prior to planting must be discounted. The degree of substitution will depend on the price of the recovery products relative to the products now used.

As a basis for establishing market potential for the recovery products, two levels of consumption density were

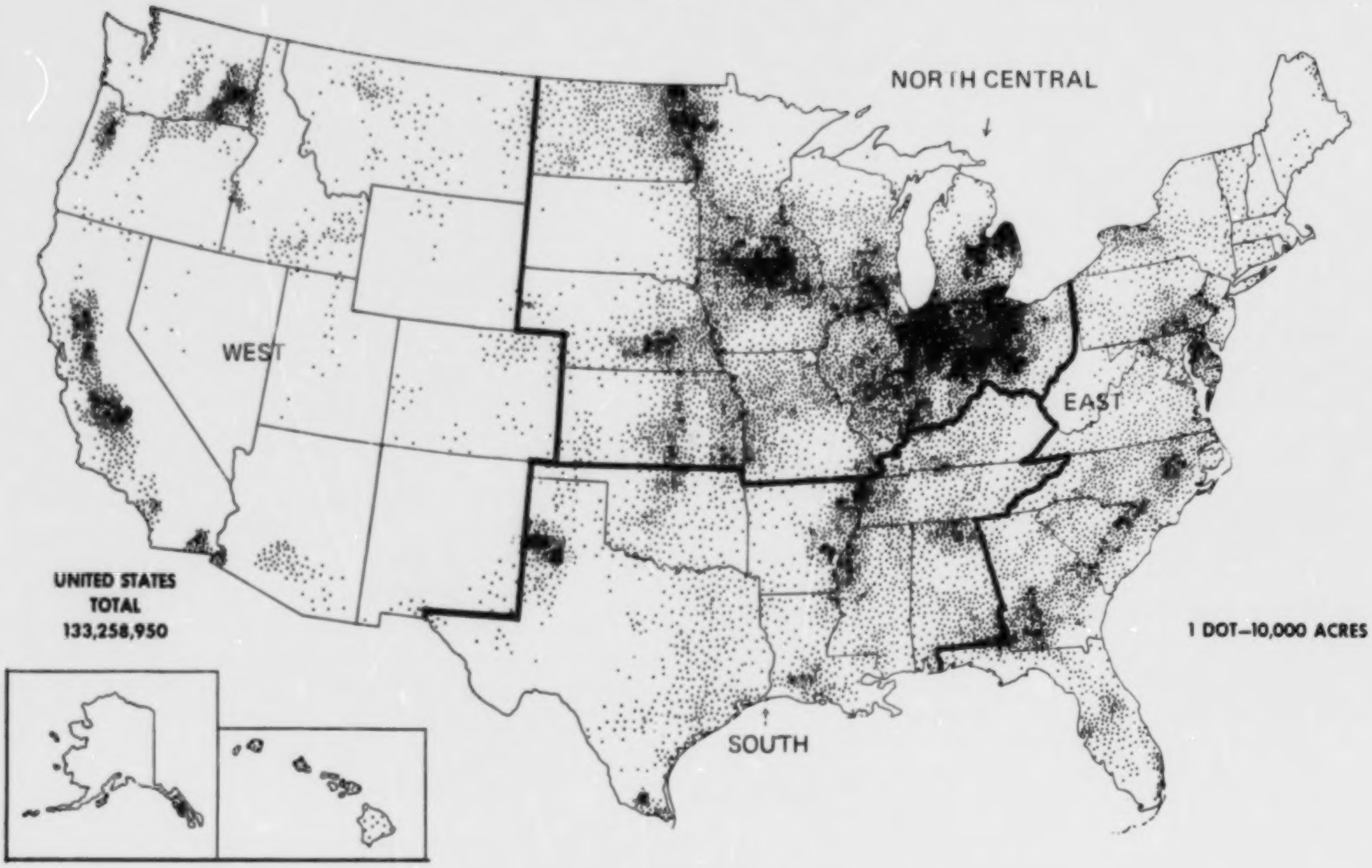


Figure 57. Fertilizer Use Pattern in the United States

Table 23. Competitive Bulk-Blending Prices for Standard Fertilizers and for Sulfur Oxide Recovery Products (Delivered to the Midwest)

	Input price, $/ton	Shadow price, $/ton	
		Ammonium nitrate[a] competition	Diammonium phosphate[b] competition
Established Products[c]			
Ammonium nitrate (33.5-0-0)	45.00		
Diammonium phosphate (18-46-0)	73.00		
Triple superphosphate (0-46-0)	56.00		
Sulfur Recovery Products			
Ammonium phosphate nitrate (28-14-0)		52.47	43.49
Ammonium phosphate nitrate (26-19-0)		55.09	47.69
Ammonium phosphate sulfate (19-14-0)		42.79	37.15
Ammonium sulfate (21-0-0)		28.21	19.83

[a] Nitrogen cost = (45.00/0.335) = $134.33/ton.
Phosphate cost = (73 - [134.33] 0.18)/0.46 = $106.13/ton.

[b] Phosphate cost = (56.00/0.46) = $121.74/ton.
Nitrogen cost = (73 - 46)/0.18 = $94.44/ton.

[c] These prices are manufacturers' list prices for the winter of 1969, with $13/ton freight added to the phosphate products (shipped from Tampa, Florida). Actual prices at that time were being discounted 20%, but are expected to recover to the above levels in the long-run.

assumed. The lower level (0.25 tons N/sq mile) corresponds to approximately 10% of the solids used for direct application and all of the straight nitrogen solids used in custom blends. The higher level (1.0 ton N/sq mile) corresponds to replacing all the solid nitrogen products in blends, approximately 20% of the direct application solid fertilizer, and 75% of the 18-46-0 (diammonium phosphate) used in commercial mixtures.

The higher level is probably not realistic for the early yrs but with gradual penetration and market growth (estimated at 6% annually) it is reasonable to consider it as an average over the life of the recovery plant.

Pricing of Recovery Products

Base Price—If the recovery products are priced so that a bulk blender realizes lower costs, it is reasonable to assume that he will substitute them for his present raw material inputs. Table 23 lists the assumed prices for the major established products and the maximum prices a blender could pay for the substitution products (hereinafter called "shadow prices"). The fertilizer prices assumed in table 23 are estimates of long-run levels in terms of current dollars. In late 1968 actual prices were about 20% below these but at this writing (late 1969), prices seem to be recovering. It is expected that they will recover to the long-run estimates and thereafter reflect price levels of the general economy.

As an aid to understanding the shadow prices shown in table 23, consider the following example. Suppose that a blender has a market for 3000 tons of plant nutrient/yr in a 1:1:1 fertilizer ratio. He can purchase the established products at the input prices given in table 23. (The price of potassium chloride is immaterial in the present example since it is the only potash source considered.) Suppose that it has been decided to produce 28-14-0 at the power plant, but it has not yet been decided how much to supply at any given point in the market. It is assumed, however, that whatever quantity is supplied will be such a small part of the total market that the 28-14-0 supplier does not expect his supply will affect the market prices of other established products.

With this in mind, consider figure 60. The horizontal axis indicates the quantity of 28-14-0 supplied to and purchased by the blender in question. The lower curves give on the right-hand ordinate the quantities of the other inputs that would be needed to supply the 3000 tons of nutrient/yr if the corresponding quantities of 28-14-0 were used. The upper curve is the blender's demand curve for 28-14-0 and gives the maximum price he can pay for a particular quantity of 28-14-0 (based on table 23). If the price of 28-14-0 were higher than the indicated \$52.47/ton, it would not pay him to use any of this product. He would use 33.5-0-0 and either 18-46-0 or 0-46-0, depending on which minimizes the cost. In arriving at this least-cost decision, the blender calculates his nitrogen cost on the basis of 33.5-0-0 as \$45.00/0.335 = \$134.33/ton of nitrogen. If 0-46-0 were to be used, the phosphate cost would be calculated as \$56.00/0.46 = \$121.74/ton of P_2O_5. With 18-46-0 as the phosphate source, the phosphate cost is calculated as

$$\frac{\$73.00 - (\$134.33)0.18}{0.46} = \$106.13/\text{ton of } P_2O_5$$

which is equivalent to removing the value of the 0.18 tons of nitrogen in 18-46-0 as ammonium nitrate and treating the residual value as being that of 0.46 tons of P_2O_5. It can be seen that the use of 18-46-0 results in a phosphate cost which is \$15.61/ton of P_2O_5 less than the equivalent cost of 0-46-0. The shadow price of 28-14-0 is calculated as (\$134.33)0.28 + (\$106.13)0.14 = \$52.47/ton.

After substitution for all of the 33.5-0-0, further increase in use of 28-14-0 requires not only the substitution of 28-14-0 nitrogen for 18-46-0 nitrogen, but 0-46-0 phosphate for 18-46-0 phosphate. The cost of added phosphate in this substitution is calculated as \$56.00/0.46 = \$121.74/ton of P_2O_5, which, as noted in the initial least-cost decision, is a \$15.61/ton P_2O_5 increase in the phosphate cost. At this higher phosphate cost, 28-14-0

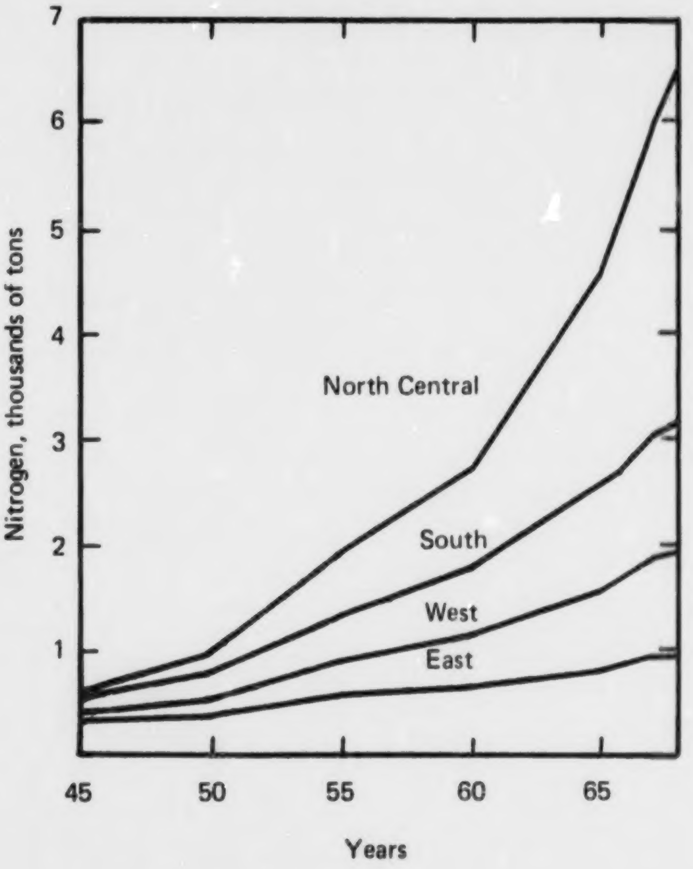


Figure 58. U. S. Nitrogen Fertilizer Consumption by Regions (1945-1968)

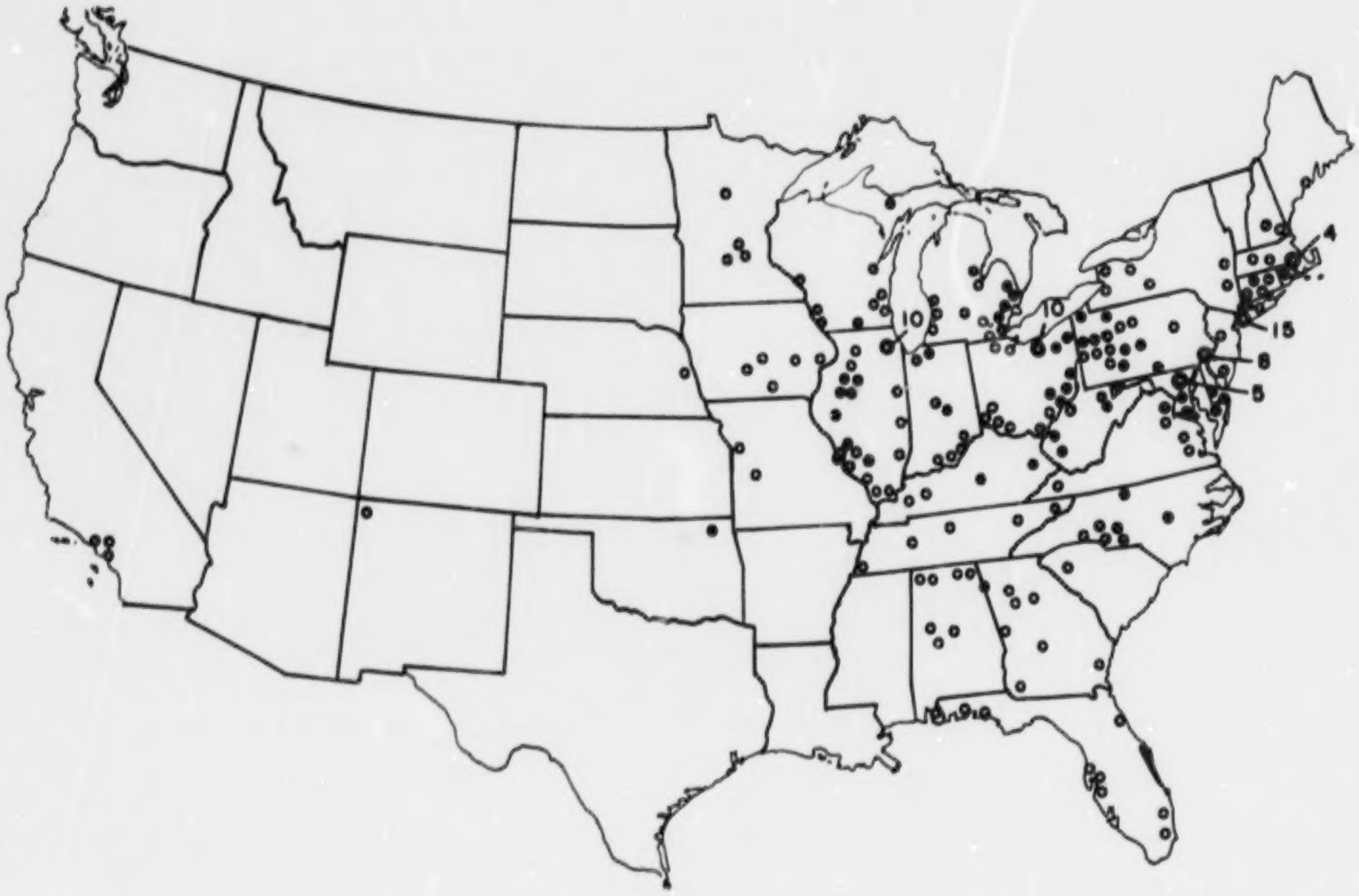


Figure 59. Approximate Location of Major Thermal Power Plants

must be sold at a correspondingly lower price. The nitrogen in 28-14-0 is worth only

$$\frac{\$73.00 - \$56.00}{0.18} = \$94.44\text{/ton of nitrogen}$$

and the product is worth only (\$94.44) 0.28 + (\$121.74) 0.14 = \$43.49/ton.

Market Strategy—In view of the differing substitution price levels and consumption densities, it is desirable to develop a market strategy that will optimize the relation between sales price and transportation cost. This is merely a matter of the producer setting a price, for a given production level, that will maximize the net sales revenue. Higher price (within realistic limits) maximizes gross return but requires a larger sales area for such a "skim the cream" marketing strategy and consequently a higher total transportation cost. Lower prices reduce gross return but also decrease shipping charges.

For the situation in question, there are four main pricing strategies to be considered: (1) fob basis (highest price level at which all the product can be sold at the plant), (2) delivered basis, competitive with ammonium nitrate (requires longest shipping distance), (3) delivered basis, competitive with diammonium phosphate (lower price level but lower shipping cost), and (4) a dual-zone basis (combination of 3 and 4). Analysis of these alternatives is a complicated matter and is discussed in detail in Appendix A. Based on this analysis, it is concluded that except for very large quantities from a single production point (over 400,000 tons of N/yr, outside the production capacities assumed in the present study), pricing the recovery products to compete with ammonium nitrate is the most economical approach. Average return to manufacturing ("net back") on this basis is shown for each product as a function of production quantity of nitrogen in figures 61-64. Net returns were also assembled for each of the process variable combinations (tables 24-27).

Extent of Market for Recovery Products—The subject of the present study is the economic viability of a single large plant, but the question of maximum utility of the process is also of interest. It is assumed that initially only a few power plants would be equipped with ammonia scrubbing-nitric phosphate facilities and that they would be

Table 24. Average Return to Manufacturing[a]
Process A (28-14-0)

Power plant			Annual operating hours							
			7,000		5,000		3,500		1,500	
Size, mw	Type New or existing	S in coal, % by wt	Tons N/yr	$/ton of fertilizer	Tons N/yr	$/ton of fertilizer	Tons N/yr	$/ton of fertilizer	Tons N/yr	$/ton of fertilizer
200	E	3.5	128,600	42.46	91,700	42.86	64,200	43.21	27,600	43.82
500	N	2.0	173,600	42.06	123,900	42.52	86,700	42.92	37,200	43.63
500	N	3.5	303,800	41.12	217,000	41.71	151,900	42.23	65,300	43.18
500	E	3.5	310,800	41.07	222,000	41.68	155,400	42.22	66,800	43.17
500	N	5.0	434,000	40.36	309,800	41.08	217,000	41.71	92,800	42.86
1,000	N	3.5	587,500	39.61	419,700	40.44	293,800	41.18	126,300	42.49
1,000	E	3.5	607,600	39.53	433,800	40.36	303,700	41.12	130,100	42.45

[a] Based on delivered price competitive with ammonium nitrate.

Table 25. Average Return to Manufacturing[a]
Process B (26-19-0)

Power plant			Annual operating hours							
			7,000		5,000		3,500		1,500	
Size, mw	Type New or existing	S in coal, % by wt	Tons N/yr	$/ton of fertilizer	Tons N/yr	$/ton of fertilizer	Tons N/yr	$/ton of fertilizer	Tons N/yr	$/ton of fertilizer
200	E	3.5	97,100	45.17	69,500	45.50	48,600	45.79	20,800	46.30
500	N	2.0	131,500	44.84	93,900	45.22	65,800	45.55	28,200	46.15
500	N	3.5	230,000	44.04	164,300	44.54	115,000	44.99	49,300	45.78
500	E	3.5	235,800	44.00	168,200	44.51	117,900	44.96	50,500	45.75
500	N	5.0	328,600	43.41	234,700	44.01	164,300	44.54	70,400	45.48
1,000	E	3.5	460,000	42.70	328,600	43.41	230,000	44.04	98,500	45.16
1,000	N	3.5	444,000	42.78	318,000	43.49	222,000	44.11	95,200	45.22

[a] Based on delivered price competitive with ammonium nitrate.

Table 26. Average Return to Manufacturing[a]
Process C (19-14-0)

Power plant			Annual operating hours							
			7,000		5,000		3,500		1,500	
Size, mw	Type New or existing	S in coal, % by wt	Tons N/yr	$/ton of fertilizer	Tons N/yr	$/ton of fertilizer	Tons N/yr	$/ton of fertilizer	Tons N/yr	$/ton of fertilizer
200	E	3.5	56,700	35.05	40,500	35.27	28,400	35.47	12,200	35.82
500	N	2.0	76,600	34.82	54,700	35.06	38,300	35.30	16,400	35.70
500	N	3.5	134,000	34.30	95,700	34.63	67,000	34.93	28,700	35.46
500	E	3.5	137,000	34.27	97,900	34.61	68,500	34.91	29,400	35.45
500	N	5.0	191,400	33.87	136,700	34.27	95,700	34.63	41,000	35.27
1,000	E	3.5	268,000	33.40	191,400	33.87	134,000	34.30	57,400	35.04
1,000	N	3.5	259,500	33.44	185,400	33.91	129,800	34.33	55,600	35.06

[a] Based on delivered price competitive with ammonium nitrate.

Table 27. Average Return to Manufacturing[a]
Ammonium Sulfate

Power plant			Annual operating hours							
			7,000		5,000		3,500		1,500	
Size, mw	Type New or existing	S in coal, % by wt	Tons N/yr	$/ton of fertilizer	Tons N/yr	$/ton of fertilizer	Tons N/yr	$/ton of fertilizer	Tons N/yr	$/ton of fertilizer
200	E	3.5	65,860	22.08	47,000	22.32	32,900	22.53	14,100	22.91
500	N	2.0	89,000	21.82	63,600	22.10	44,500	22.35	19,100	22.79
500	N	3.5	155,925	21.23	111,400	21.61	78,000	21.94	33,400	22.52
500	E	3.5	159,500	21.21	113,900	21.59	79,800	21.92	34,200	22.51
500	N	5.0	222,810	20.77	159,200	21.21	111,400	21.61	47,700	22.31
1,000	E	3.5	311,850	20.24	222,800	20.77	155,900	21.23	66,800	22.06
1,000	N	3.5	301,560	20.29	215,400	20.81	150,800	21.27	64,600	22.08

[a] Based on delivered price competitive with ammonium nitrate.

located with a minimum of market overlap. Assuming a hypothetical central Illinois plant with 500-mw capacity, the market boundaries for 19-14-0 and 28-14-0 based on 0.25 consumption density are shown in figure 65. The area covered indicates that only two or three plants could be accommodated without serious overlap if 28-14-0 is produced. With production of 19-14-0, about three times as many plants could utilize the process. The limiting competitive case is that which results in diammonium phosphate competition (consumption density of 1.0) at all points. Market boundaries for such a case are shown in figure 66.

PROFITABILITY

If chemical companies enter into the sulfur recovery field, on the basis either of contributing all the investment or of supplying only part of it, profitability of the venture becomes of paramount importance. An unregulated company, with no guarantee of sales price or net profit and with all the uncertainties associated with the future of chemical enterprises, must be able to see promise of a relatively high rate of return in order to attract capital to the project.

The cost of recovering sulfur oxides and the revenue from sale of product have been estimated in previous sections. Another source of income can also be considered, namely a payment by the power producer to the chemical company for performing the service of pollution abatement. This seems reasonable since the power company must incur a considerable cost in any event for removing sulfur oxides from the gas (unless it reduces or eliminates this cost by entering into a recovery project itself).

The amount of payment presumably would be negotiated between the two companies, and could range from zero to the full cost of lime or limestone scrubbing. Hence the profitability estimates in the present study have been calculated on two bases—full payment (equivalent to lime-limestone scrubbing cost) and no payment. In practice, the payment might well be in between.

The above applies to the situation in which the chemical company finances and operates the entire installation, including scrubbing. For the joint venture approach, several different arrangements are conceivable. In the one selected for the present study, the power company finances and operates a stack gas scrubbing and reheat system under regulated economics and sells the intermediate scrubber effluent to a fertilizer company. The fertilizer company is assumed to invest in an adjacent on-site plant for further processing the intermediate into product and to market the product with the expectation of attaining an adequate return on investment. Because the power company will be seeking to minimize the cost to power consumers by attaining the highest possible "transfer price" for the intermediate, and the fertilizer company will be seeking the lowest possible price for the "raw material" to maximize return on investment, a critical part of this concept depends on the negotiated price. The fertilizer company cannot afford to pay more than the price at which the intermediate could be obtained elsewhere. On the other hand, the power company cannot go lower than the level at which the net cost of the scrubbing operation becomes higher than for the alternative lime scrubbing method.

Once again, as with the "payment" under full nonregulated economics, only a range can be established in regard to the loss the power company can afford to incur and pass on to the fertilizer company as a "deduction." Therefore, the operating cost to the fertilizer company is presented in two ways—with a raw material cost equivalent to (1) that required to give normal return to the power plant on the scrubbing operation and (2) that resulting from the power plant incurring a loss equal to the cost of lime scrubbing.

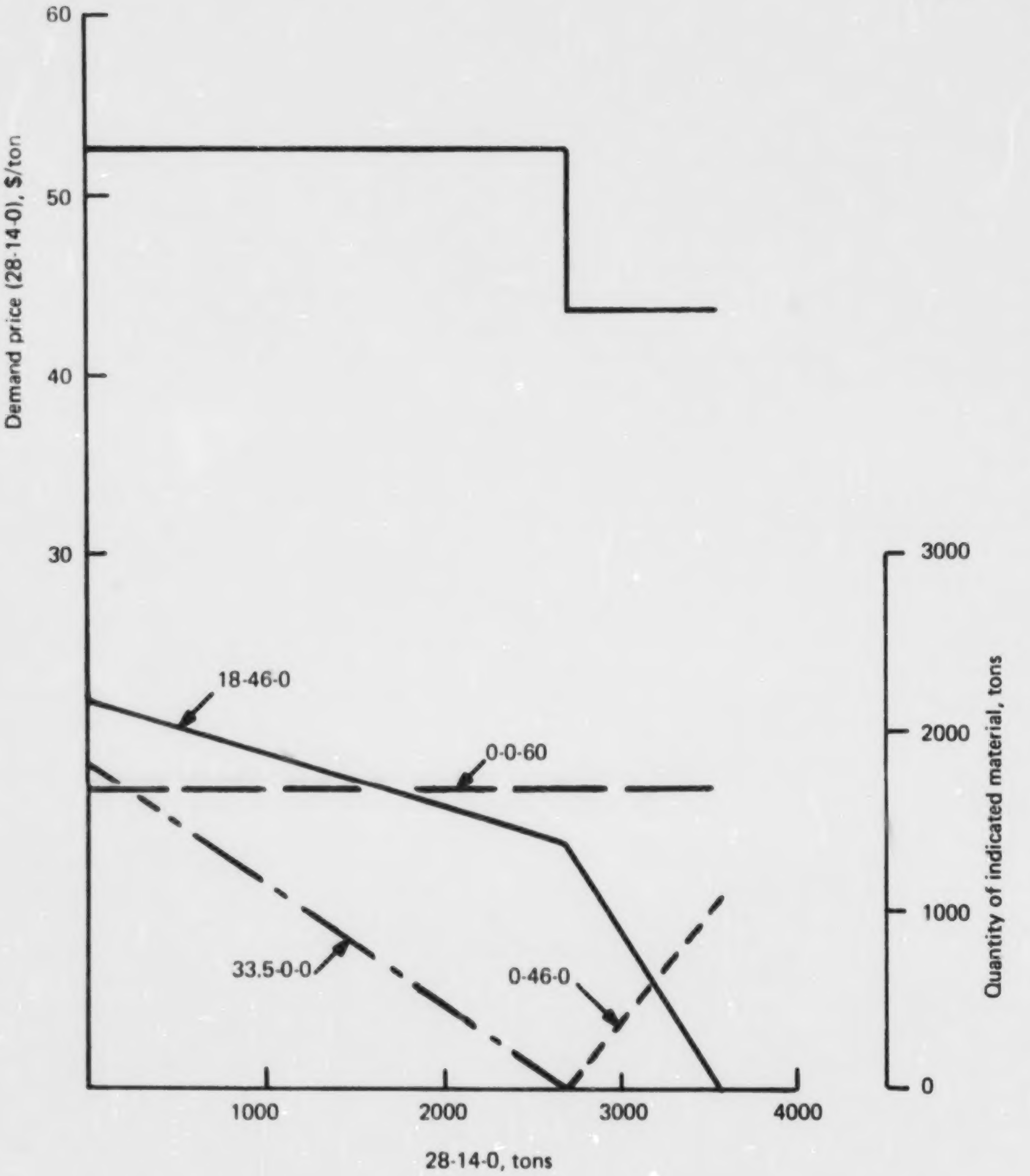


Figure 60. Substitution of Byproduct 28-14-0 for Ammonium Nitrate and 18-46-0 at Specified Competitive Price Conditions

So that consistent comparisons can be made of the three processes under consideration, the processes are split arbitrarily after the point where ammonium sulfate is produced. All prior operations are costed on the basis of regulated economics and the remainder on unregulated economics.

The question regarding the attractiveness of a process for chemical industry investment can be answered best by applying a venture appraisal method that relates profit-making potential to the investment requirements. Several types of venture appraisal techniques are used in nonregulated industry; three of the more common ones

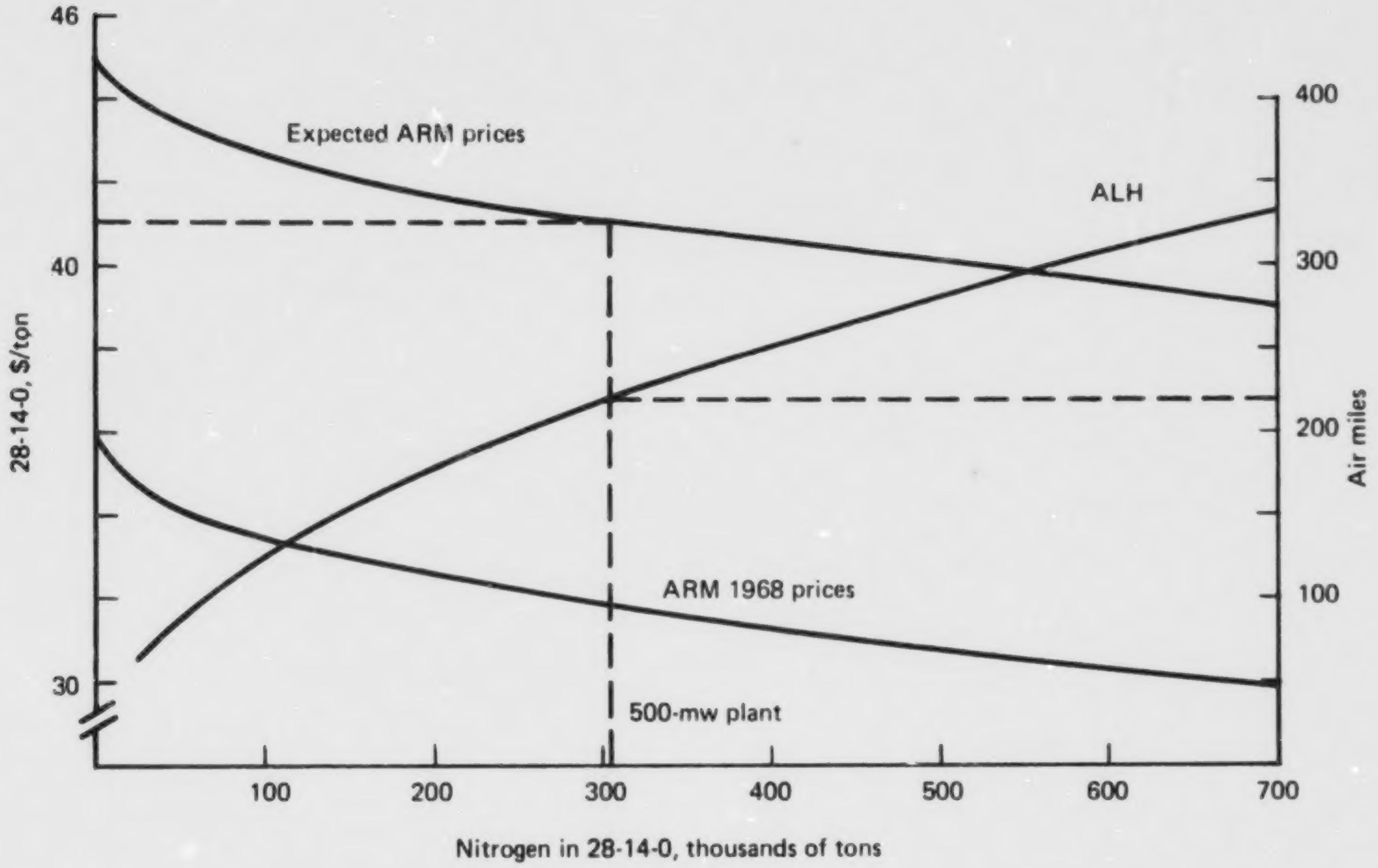


Figure 61. Average Return to Manufacturing (ARM) and Average Length of Haul (ALH) for 28-14-0 (Based on Delivered Price Competitive with Ammonium Nitrate)

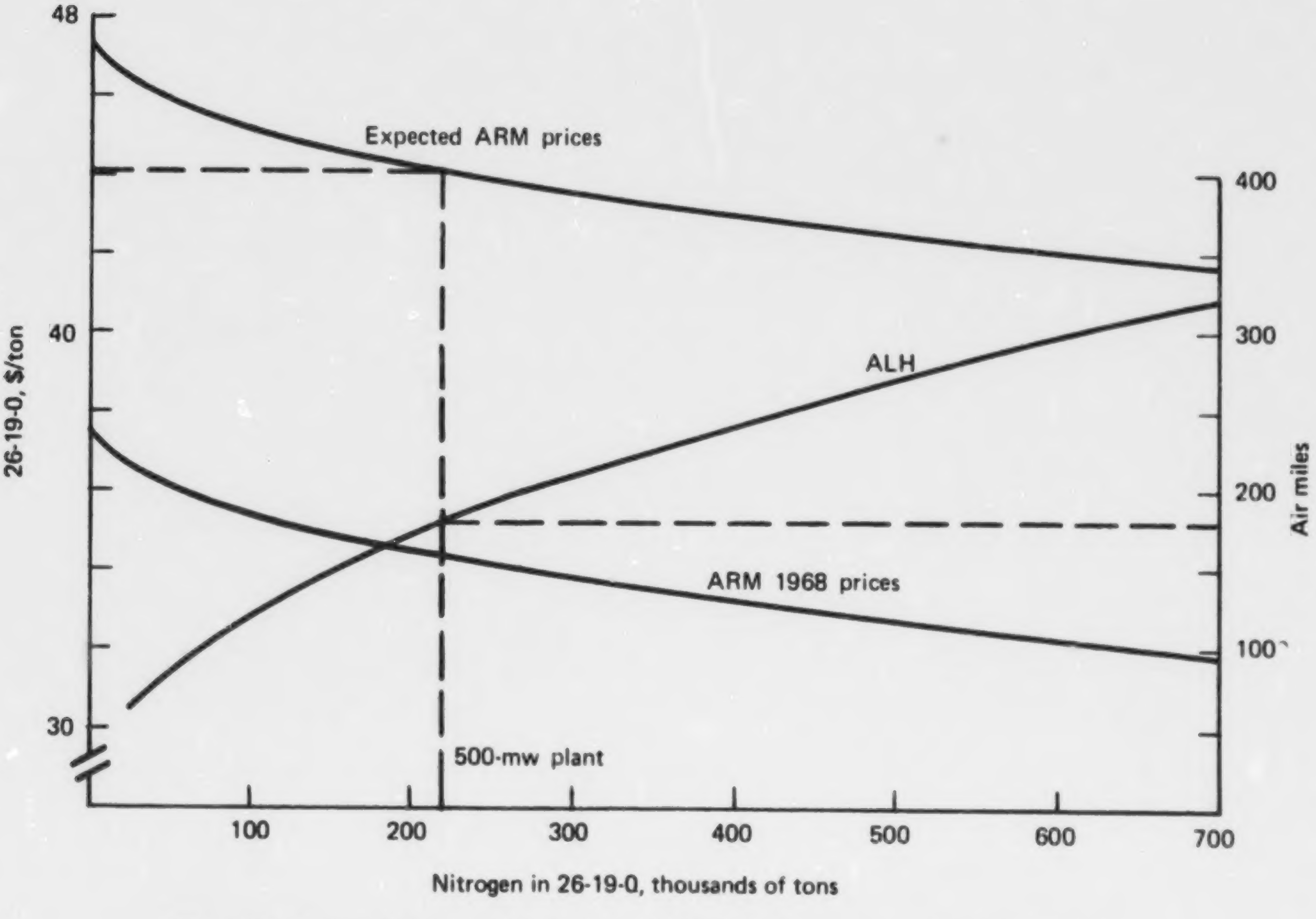


Figure 62. Average Return to Manufacturing (ARM) and Average Length of Haul (ALH) for 26-19-0 (Based on Delivered Price Competitive with Ammonium Nitrate)

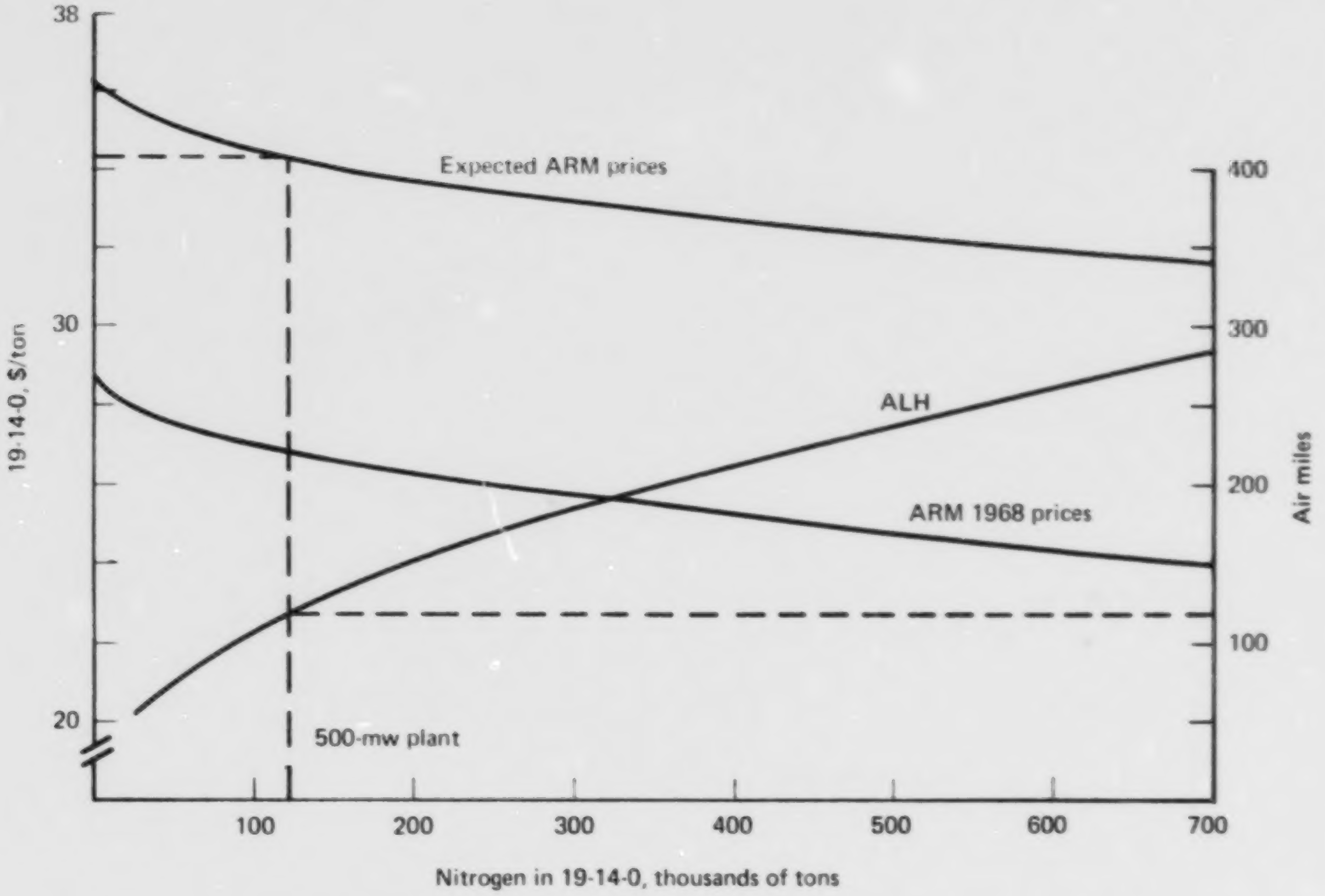


Figure 63. Average Return to Manufacturing (ARM) and Average Length of Haul (ALH) for 19-14-0 (Based on Delivered Price Competitive with Ammonium Nitrate)

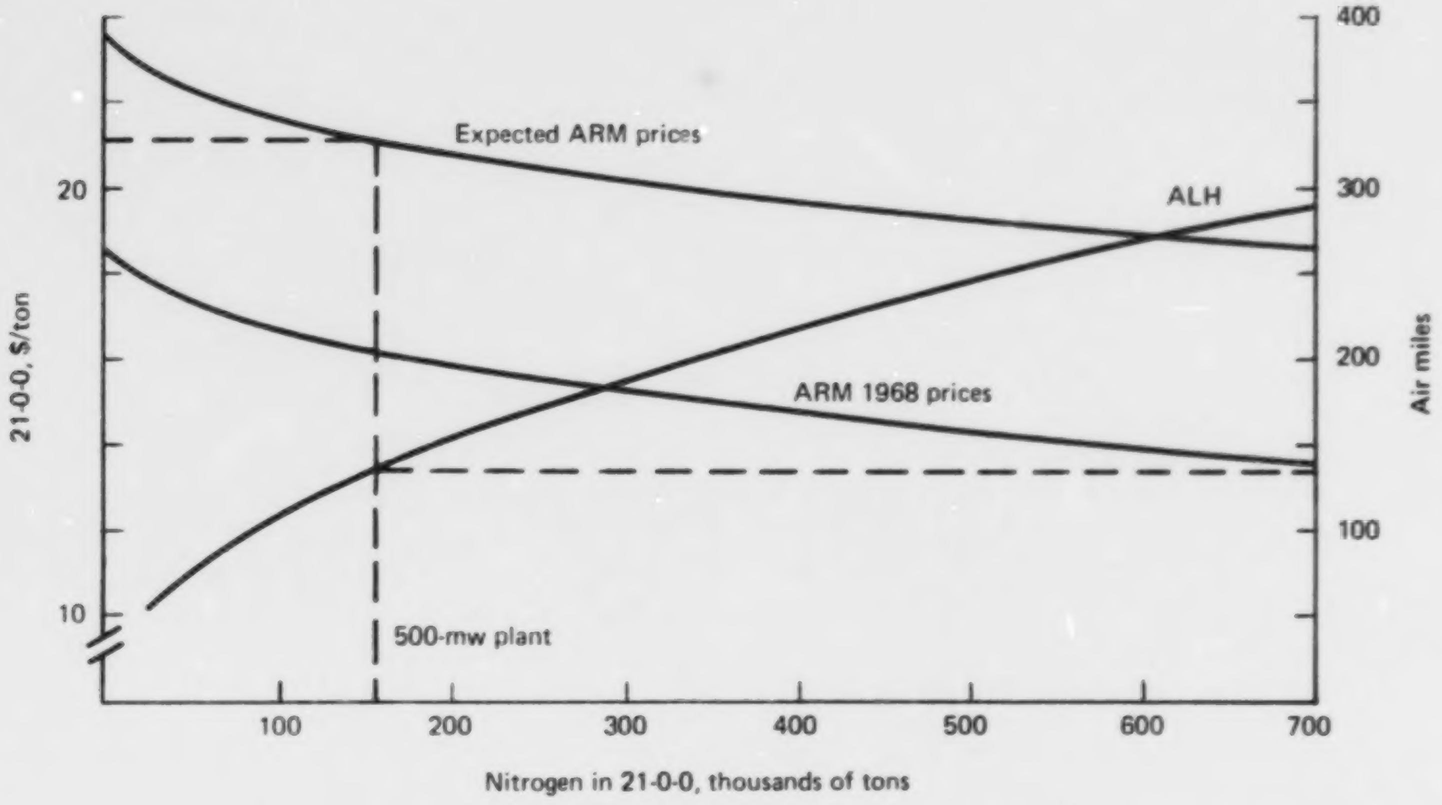


Figure 64. Average Return to Manufacturing (ARM) and Average Length of Haul (ALH) for 21-0-0 (Based on Delivered Price Competitive with Ammonium Nitrate)

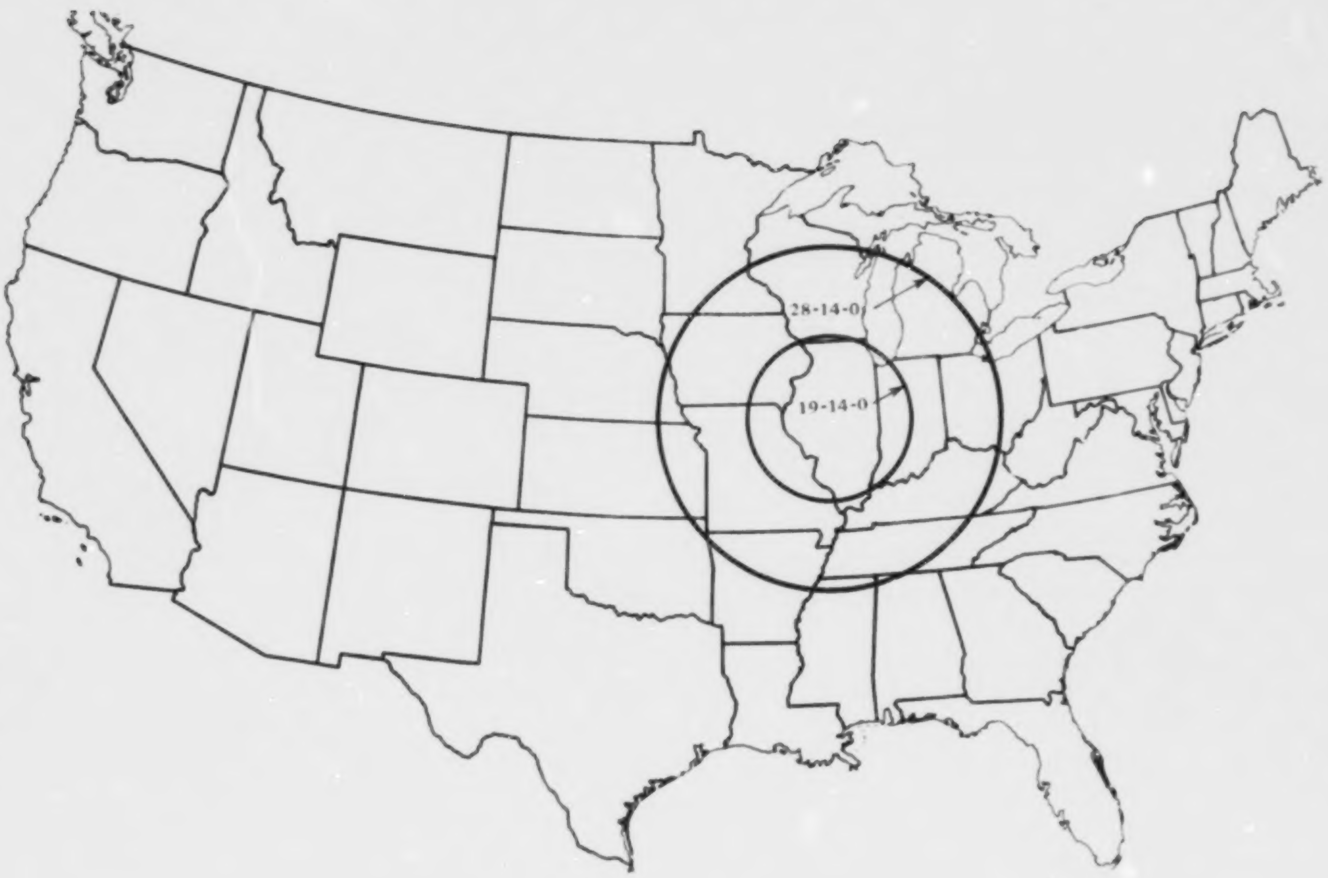
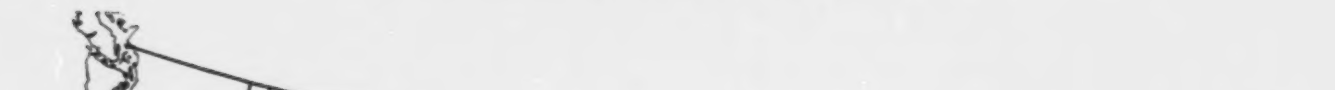


Figure 65. Expected Market Boundaries for 28-14-0 and 19-14-0 for Ammonium Nitrate Competition and a 500-mw Plant



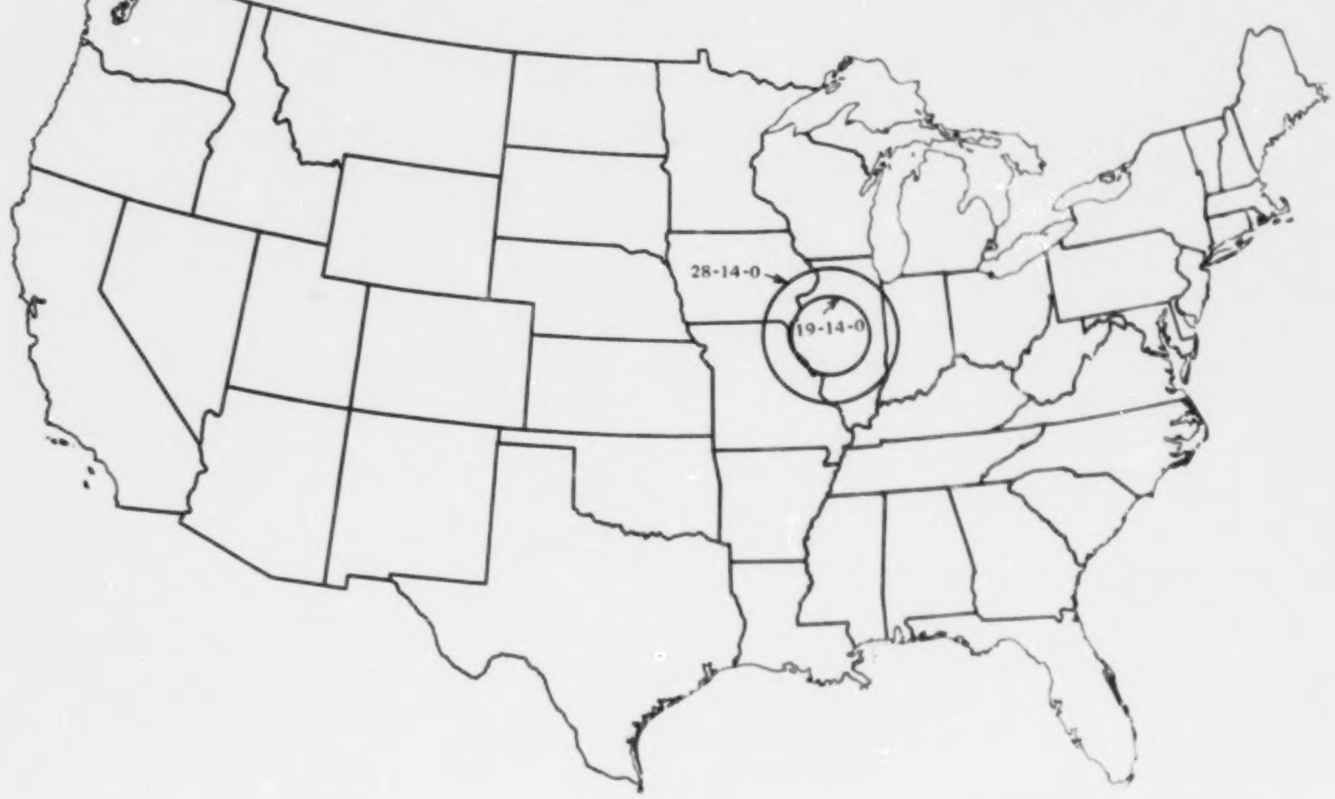


Figure 66. Ultimate Competitive Market Boundaries for 28-14-0 and 19-14-0 for Diammonium Phosphate Competition and a 500-mw Plant

(annual return on initial investment, payout period, and interest rate of return) have been calculated in the present study for all applicable cases where nonregulated industry economics are involved. The annual return on investment is defined as the annual net income after taxes divided by the initial total investment including working capital; the composite tax rate for nonregulated industry is assumed to be 50% of gross income. Payout period is the number of years required to recover the initial investment by cash flow (depreciation plus net income after taxes). Interest rate of return, sometimes referred to as discounted cash flow, is best described as the interest rate at which the sum of the present worth of the yearly receipts (depreciation plus after-tax profit) becomes equal to the sum of the present worth of the disbursements. Another definition is the interest rate a savings bank would have to pay to accept and return cash on the same schedule as the proposal. Of the three methods, only interest rate of return recognizes the time value of money.

Results of the profitability estimates are presented as computer print-outs in Appendix B. Operation of the entire facility by the fertilizer company (nonregulated economics) is covered in tables B-106–B-126 and joint venture (cooperative) operation in tables B-127–B-147. Each yr of operation is calculated separately to cover the adverse effect of declining operating factor on profitability in the later yrs of power plant operation. Gross income is calculated as sales revenue plus the pollution abatement payment, if any, less manufacturing cost; deduction of income tax then gives the total net income/yr.

The estimates show that net income varies widely depending on several factors. Under some conditions (small plant size, low sulfur content of coal, no pollution abatement payment, later yrs of operation), there is a loss rather than net income. On the other hand, at the other extreme of these variables net income is high—particularly in the early yrs of operation.

Full evaluation of a nonregulated venture must include cash flow (depreciation plus net income) and an analysis of economic promise at the time of going into the venture. This is considered in detail in the next section.

ECONOMIC EVALUATION

Basic Economics of Fertilizer Process

The fertilizer process in question, production of nitric phosphate by calcium precipitation with ammonium sulfate, has been used commercially in Europe but not in the United States. Presumably the European company, a large and successful one, found the method economically attractive. However, the ammonium sulfate used is a byproduct from a chemical process and it is not known at what price it is charged to the nitric phosphate plant; moreover, market conditions differ between Europe and the United States. Therefore, the first step in the present analysis was an estimate based on U. S. conditions to establish the basic economics of the nitric phosphate process without reference to power plants. The possibility exists, of course, that in the United States the process would not be attractive even under the most favorable situation that could be visualized.

As a starting point, an evaluation was prepared for operating process A without any connection to a power plant; in this case the ammonium sulfate would be recycled in the process by reacting product calcium sulfate with ammonia and carbon dioxide. Investment for the plant (process A; 1040 tons 28-14-0 fertilizer/day, equivalent to production from a 500-mw power plant burning coal containing 3.5% S) is given in table 28 and operating cost (8000 hr/yr; indirect costs on nonregulated industry basis) in table 29. Profitability was then calculated on the basis of the sales revenue estimated for this level of production (unit price for product varies with production level). The result was 6.5% annual return on initial investment, 10% interest rate of return (over 10 yr, to end of depreciation period), and 6.1 yrs payout time.

It is difficult to say whether this degree of profitability is large enough to attract investors. Each company has its own criteria as to what it considers to be an attractive investment opportunity and no generally applicable standard can be set. However, a rough concensus appears to be 7-10% annual return on investment, 12-15% interest rate of return, and less than 6 yrs payout time. On this basis, the nitric phosphate process is on the low side for the 500-mw size assumed in the estimate. Profitability could be improved, however, by increasing either the plant size (to reduce operating cost) or the sales revenue; for example, an increase in the price of sulfur to the fertilizer industry would operate indirectly to increase sales price realizable for the nitric phosphate product. Rough estimates (not reported) indicate that a 5-yr payout (15% interest rate of return for 10-yr life) could be obtained by increasing the plant size to that equivalent to an 800-mw power plant or by increasing the sales revenue by 10%. Moreover, it is likely that in practice the nitric phosphate plant would be operated in conjunction with an ammonia plant, in which case reduction in sales, handling, and overhead costs would reduce the ammonia cost as compared with purchasing the ammonia; a reduction of $5/ton of ammonia might well be possible, which would increase interest rate of return from 10% up to 12.6%. Finally, the economics could be improved if the process were tied to a power plant and if such joint operation made it possible to obtain the ammonium sulfate at a cost lower than by making it from gypsum.

The cost of making ammonium sulfate by gypsum

Table 28. Summary of Estimated Fixed Investment Requirements:[a] Manufacture of 28-14-0 Fertilizer by Sulfate Recycle - Nitric Phosphate Process
(43.4 tons/hr of fertilizer)

	Investment, $
Yard, utilities, and storage facilities (raw material storage, railroad unloading and shipping, and utilities distribution)	2,043,000
Gypsum conversion unit (sulfate recycle by ammonium carbonate reaction)	680,000
Nitric acid plant (60% nitric acid)	3,200,000
Extraction-filtration (equipment for acidification of phosphate rock, ammonium sulfate addition, and gypsum filtration)	1,100,000
Neutralization and prilling (equipment for neutralization, evaporation, prilling, screening, and conveying product)	3,830,000
Bulk storage (storage and shipping bulidings, 90 days' storage)	1,770,000
Waste disposal (calcium carbonate disposal including pond)	200,000
Subtotal direct investment	12,823,000
Engineering design	1,046,000
Contractor fees and overheads	1,581,000
Contingency allowance	1,287,000
Total fixed investment	16,737,000

[a] Basis:
Capacity of unit same as provided by 500-mw power unit burning coal with 3.5% S using ammonia scrubbing of stack gas. Carbon dioxide and ammonia assumed available from adjacent facilities.

conversion is given in table 30 and 31. Assuming a 20% annual return before taxes on initial investment (10% net return; 15% interest rate of return over 10 yr), the price at which the ammonium sulfate solution would be charged to the nitric phosphate plant is $14.35/ton of ammonium sulfate (process A). The cost for making it by ammonia scrubbing of power plant stack gas varies with several factors: sulfur content of the coal, operating factor of the power plant, choice between regulated and nonregulated economics (or combination thereof), and new vs existing power plant. For a comparable amount of ammonium sulfate, the variation is from about $16 to well over $20/ton (see Appendix B). Hence tying the fertilizer plant to the power plant (as opposed to operating the fertilizer plant independently with ammonium sulfate made by gypsum conversion) would not be justified economically unless some credit were allowed for air pollution control. The alternative cost for limestone - wet scrubbing, expressed for convenience as the cost of removing an amount of sulfur dioxide equivalent to a ton of ammonium sulfate, ranges from $9-12. Hence if the power company were willing to operate an ammonia scrubbing unit at the same net cost as limestone - wet scrubbing, the ammonium sulfate could be transferred to the fertilizer plant at a charge of only $7.30-10.10/ton.

Thus the economics of making ammonium sulfate by scrubbing stack gas and using the ammonium sulfate in a nitric phosphate process appear favorable if the fertilizer unit is given at least partial credit for pollution control.

Fertilizer Company Involvement

Since the comparable economics of using byproduct ammonium sulfate solution from a power plant as a raw material for nitric phosphate production appear acceptable, the next step is to assess the economic promise for the various combinations of conditions. To do this, the payout periods and interest rates of return calculated from the projected cash flows (tables B-106 - B-147 in Appendix B) are assembled in table 32.

The data indicate that under certain conditions both processes A and B merit consideration as reasonably attractive financial ventures. In most of the process C cases, however, the initial investment is not even recovered, since interest rate of return is negative. Process A is slightly more attractive than process B, having a marginally higher interest rate of return and a lower payout period. For these processes to be attractive, however, some credit for pollution control would be needed and fertilizer tonnage would have to be large. In general, it appears that power units must be larger than 500 mw and burn coal containing at least 3.5% sulfur to give acceptably profitable operation.

For smaller power units, the joint venture approach (cooperative economics) is generally a little less attractive than total investment and operation by the fertilizer company (unregulated economics). The reasons for this are quite complex because several factors, some varying in effect with the magnitude of others, affect the relative rates of return over the operating lifetime of the plant. The main

Table 29. Nonregulated Company Economics - Total Venture Annual Manufacturing Costs for 28-14-0 Fertilizer Using Ammonium Sulfate Recycle and Nitric Phosphate Process[a]
(347,000 tons/yr fertilizer)

	Annual quantity	Unit cost, $	Total annual cost, $	Cost/ton of fertilizer, $
Direct Costs				
Delivered raw material				
Ammonia	116.2 M tons	35.00/ton	4,067,000	
Phosphate rock	143.9 M tons	11.88/ton	1,709,500	
Carbon dioxide	67.6 M tons	1.00/ton	67,600	
Sulfuric acid	9.6 M tons	23.00/ton	220,800	
Conditioner	6.0 M tons	46.60/ton	279,600	
Antifoam	115.2 M lb	0.18/lb	20,700	
Nitric acid catalyst	570 troy oz	120/troy oz	68,400	
Subtotal raw materials			6,433,600	
Conversion costs				
Operating labor and supervision	100,000 man-hr	4.50/man-hr	450,000	
Utilities				
Steam	1,112,000 M lb	0.40/M lb	444,800	
Water	5,254,000 M gal	0.05/M gal	262,700	
Electricity	35,033,000 kwh	0.005/kwh	175,200	
Maintenance				
Labor and material			784,400	
Analyses			55,000	
Subtotal conversion costs			2,172,100	
Subtotal direct costs			8,605,700	
Indirect Costs				
Depreciation at 10% of fixed investment			1,673,700	
Local taxes and insurance at 2% of fixed investment			334,700	
Overhead				
Plant, 20% of conversion costs			434,400	
Administrative, research, and service, 10% of conversion costs			217,200	
Subtotal indirect costs			2,660,000	
Total annual manufacturing costs for 28-14-0 fertilizer			11,265,700	32.46

[a] Basis:
Fertilizer plant on-stream time, 8,000 hr.
Midwest plant location—1969 costs.
Capital investment $16,737,000 fixed.
Carbon dioxide and ammonia assumed available as package from adjacent ammonia plant.
Capacity of unit same as provided by 500-mw power unit burning coal with 3.5% S using ammonia scrubbing of stack gas.

Table 30. Summary of Estimated Fixed Investment Requirements:[a] Manufacture of Ammonium Sulfate Solution from Waste Gypsum Ammonia, and Carbon Dioxide - Sulfate Recycle Process for 28-14-0 Nitric Phosphate Fertilizer
(22.3 tons/hr ammonium sulfate in a 40% solution)

	Investment, $
Premix tanks, mixers, pumps, and conveyors	47,000
Converters, mixers, heaters, and pumps	115,000
Carbonate filter system, including vacuum pumps, wash pumps, tanks	320,000
Product storage tank and pumps	87,000
Carbonate reactor tower pumps, heat exchangers, carbonate storage	111,000
General buildings and supporting facilities	200,000
Subtotal direct investment	880,000
Engineering design	880,000
Contractor fees and overheads	144,000
Contingency allowance	88,000
Total fixed investment	1,200,000

[a] Basis:
Capacity of unit same as provided by 500-mw power unit burning coal with 3.5% S using ammonia scrubbing of stack gas.
CO_2 and NH_3 assumed available from adjacent facilities.

factor is the fixed rate of return on the scrubber unit (treated as a cost item to the fertilizer company) in the cooperative venture as compared with a varying rate in the all-fertilizer company arrangement. Only for the largest plant sizes (highest rates of return) does the cooperative venture have an advantage. In all cases, however, the differences between the two bases are probably not large enough to be significant.

The effects of power unit size on the payout period and interest rate of return are given in figures 67-70. Only the 1000-mw size gives the desired 15% or better interest rate of return.

The important effect of the credit for air pollution control is given in figures 71 and 72. Without the credit, no combination is attractive.

Sulfur content of the coal (figures 73 and 74) has a major effect. The conclusions given earlier are for coal containing 3.5% sulfur. If the content is increased to 5%, the interest rate of return goes to well over 15% even for a 500-mw unit. Annual operating time of the system has much the same effect (figures 75 and 76); over 5000 hr/yr is necessary for the 15% return (1000 mw). It is of interest to compare these values with those for the declining operating factor assumed for an actual plant situation (figure 68), for which about 16% return is obtained at 1000 mw.

The net sales revenue, of course, is an overriding factor. The effect of change in this from the value obtained in the market study is given in figures 77-80; a 10% decrease in revenue drops the indices to unattractive levels but an increase of 10% makes even a 500-mw installation attractive.

The effect of power unit age (new vs existing), and consequent operating life of the recovery unit, is shown in figure 81. Operating times for the existing units are assumed to follow the same schedule as for the new units, with the number of yrs of 7000-hr operation being the only period affected. Because of this, the adverse effect of reduced life is more drastic than if it had been spread over the entire life.

It should be pointed out that the data on existing units does not reflect the recent special legislation which permits a fast (5-yr) amortization for a portion of the investment in pollution abatement facilities added to existing plants. Since profit-producing facilities are not included under this law and the definition of qualification is best applied to specific cases, no attempt is made to describe its effects on economics in this study.

Power Company Basis

For regulated economics, there is no credit for pollution control but instead a direct present worth comparison between the recovery (ammonia) and nonrecovery (limestone) methods (table 33). Since the basic assumption under regulated economics is that the profitability (rate of return) of the power company will be maintained, the data only indicate which process gives the minimum cost of air pollution to the power consumer. Process C is not acceptable under any conditions (net cost higher than for limestone - wet scrubbing), and A and B have an advantage only for the 1000-mw size (except for a new 500-mw unit burning coal containing 5% S). However, from the curves given in figure 82, it can be seen that although limestone scrubbing is slightly less costly at 500 mw (new plant, 3.5% S), the situation is reversed at a little above 500 mw. The curves diverge rapidly so that at about 600 mw and above there is a clear advantage for ammonia scrubbing. Moreover, projection of the curves indicates that process A might even reduce the cost of power to consumers when used on new units greater than 1100 mw in size.

In contrast, figure 68 shows that under nonregulated economics the plant size would have to be about 1000 mw to give the assumed minimum interest rate of return of 15%, even with full credit for the cost of removing sulfur oxides by lime-limestone scrubbing. This major difference results from the lower rate of return acceptable in the regulated power industry.

Increase in sulfur content of the coal also improves recovery economics rapidly (figure 83). Even for 500 mw, ammonia scrubbing becomes preferable to limestone scrubbing at a little above 3.5% sulfur, and at 5.5% process A would reduce the cost of power to consumers.

Improvement in operating factor may be one of the better ways to improve economics (figure 84); for example, if a lifetime operating time of 7000 hr/yr (80% operating factor) could be maintained, even an 800-mw unit would reduce the cost of power. Provision of surge capacity between power and fertilizer plants, scrubbing of only part of the gas, and other methods might be used to increase operating factor; these could not be evaluated fully in the present study.

Sales revenue obviously is highly important also under regulated economics (figure 85 and 86). It is so important, in fact, that the difficulty in predicting future sales revenue may be an argument for selecting limestone - wet scrubbing unless the cost estimate for the particular situation indicates an advantage for the recovery process.

Table 31. Annual Manufacturing Costs: Ammonium Sulfate Solution (40%) from Waste Gypsum, Ammonia, and Carbon Dioxide · Sulfate Recycle Process for 28-14-0 Nitric Phosphate Fertilizer[a]
(178,000 tons/yr ammonium sulfate)

	Annual quantity	Unit cost, $	Total annual cost, $	Cost/ton of ammonium sulfate, $
Direct Costs				
Raw materials				
Ammonia	50.00 M tons	35.00/ton	1,750,000	
Carbon dioxide	67.6 M tons	1.00/ton	67,600	
Sulfuric acid	9.6 M tons	23.00/ton	221,000	
Gypsum waste from fertilizer process	300.0 M tons	–	–	–
Subtotal raw materials			2,038,600	
Conversion costs				
Operating labor and supervision			70,000	
Utilities				
Treated water	8,500 M gal	0.20/M gal	1,700	
Cooling water	33,000 M gal	0.10/M gal	3,300	
Electricity	2,000,000 kwh	0.008/kwh	16,000	
Maintenance				
Labor and materials			54,000	
Analyses			5,000	
Subtotal conversion costs			150,000	
Subtotal direct costs			2,188,600	
Indirect Costs				
Depreciation at 10% of fixed investment			120,000	
Taxes and insurance at 2% of fixed investment			24,000	
Overheads				
Plant, at 20% of conversion costs			30,000	
Administrative, at 40% of operating labor			28,000	
Subtotal indirect costs			202,000	
Total operating costs			2,390,600	
Credit for reduced solids disposal cost, $CaCO_3$ vs $CaSO_4$			(75,000)	
Charge for desirable return on investment by chemical company, 20% of investment before taxes			240,000	
Total annual manufacturing cost			2,555,600	14.35

[a] Basis:
Operating stream time assumed to be 8,000 hr/yr.
Capacity of unit same as provided by 500-mw power unit burning coal with 3.5% S using ammonia scrubbing of stack gas.
CO_2 assumed available as byproduct from adjacent ammonia plant. Value of waste gypsum assumed as zero.
Tons/yr of $CaCO_3$ for disposal is 75,000 less than for gypsum.

Table 32. Economic Potential of Ammonia Scrubbing - Fertilizer Production Processes

	Nonregulated economics				Cooperative economics			
	With payment[a]		Without payment		With deduction[b]		Without deduction	
Power plant	Payout yrs	Interest rate of return, %	Payout yrs	Interest rate of return, %	Payout yrs	Interest rate of return, %	Payout yrs	Interest rate of return, %
Process A								
200-mw, existing unit, 3.5% S in coal	11.4	1.5	–	–	–	–	–	–
500-mw, new unit, 2.0% S in coal	7.4	9.3	–	–	8.0	7.3	–	–
500-mw, new unit 3.5% S in coal	6.1	13.0	8.7	5.7	6.1	13.2	10.0	–
500-mw, existing unit, 3.5% S in coal	6.4	11.0	9.8	1.4	6.4	10.4	–	–
500-mw, new unit, 5.0% S in coal	5.0	17.4	6.6	11.4	4.7	18.9	6.7	11.0
1,000-mw, new unit, 3.5% S in coal	4.9	17.9	6.4	12.0	4.6	19.8	6.5	11.8
1,000-mw, existing unit, 3.5% S in coal	5.2	15.6	6.9	9.1	4.8	17.5	6.9	8.3
Process B								
200-mw, existing unit, 3.5% S in coal	14.5	0.5	–	–	–	–	–	–
500-mw, new unit, 2.0% S in coal	7.8	8.3	–	–	9.0	4.4	–	–
500-mw, new unit, 3.5% S in coal	6.3	12.5	9.4	4.0	6.4	11.9	–	–
500-mw, existing unit, 3.5% S in coal	6.4	11.1	11.3	0.8	6.5	10.1	–	–
500-mw, new unit, 5.0% S in coal	5.2	16.5	7.2	9.6	5.0	17.4	7.6	7.9
1,000-mw, new unit, 3.5% S in coal	5.1	17.3	6.9	10.5	4.8	18.7	7.3	9.0
1,000-mw, existing unit, 3.5% S in coal	5.3	15.1	7.5	7.5	5.1	15.6	8.6	3.3
Process C								
200-mw, existing unit, 3.5% S in coal	–	–	–	–	–	–	–	–
500-mw, new unit, 2.0% S in coal	–	–	–	–	–	–	–	–
500-mw, new unit, 3.5% S in coal	17.5	0.4	–	–	–	–	–	–
500-mw, existing unit, 3.5% S in coal	–	–	–	–	–	–	–	–
500-mw, new unit, 5.0% S in coal	11.0	3.3	–	–	–	–	–	–
1,000-mw, new unit, 3.5% S in coal	10.0	4.0	–	–	–	–	–	–
1,000-mw, existing unit, 3.5% S in coal	11.8	2.5	–	–	–	–	–	–

[a] Payment from power company to fertilizer company of a credit equivalent to the cost of limestone - wet scrubbing.

[b] Deduction from the price at which the power company sells ammonium sulfate to the fertilizer company; deduction equivalent to the cost of limestone - wet scrubbing.

Table 33. Present Worth[a] of the Net Annual Increase in Cost of Power Resulting From Use of the Ammonia and Limestone Scrubbing Processes

	Ammonia scrubbing-fertilizer			
Power plant	Process A	Process B	Process C	Alternate limestone - wet scrubbing process
200-mw, existing unit, 3.5% S in coal	$19,423,200	$18,957,200	$22,882,000	$ 7,219,400
500-mw, new unit, 2.0% S in coal	21,453,300	22,586,800	32,598,700	14,120,000
500-mw, new unit, 3.5% S in coal	17,156,200	18,404,200	36,843,600	16,864,800
500-mw, existing unit, 3.5% S in coal	22,400,000	21,364,600	40,208,100	16,933,200
500-mw, new unit, 5.0% S in coal	5,324,900	9,563,800	39,847,900	19,662,100
1,000-mw, new unit, 3.5% S in coal	4,594,800	9,470,500	50,606,500	26,463,500
1,000-mw, existing unit, 3.5% S in coal	16,058,000	19,161,400	55,086,300	26,919,700

[a] Cash flow discounted at 10% to initial yr.

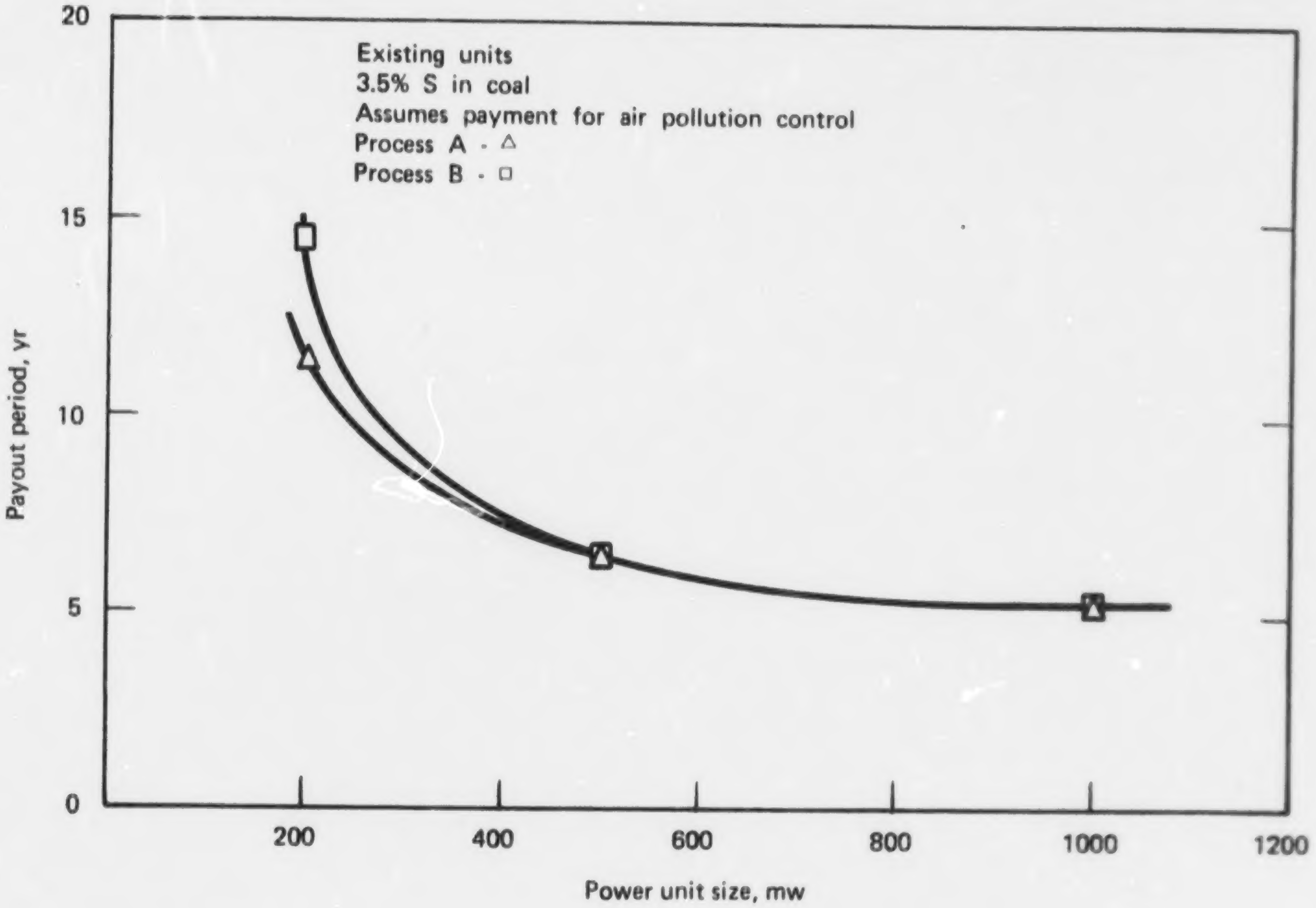


Figure 67. Effect of Power Unit Size on Payout Period for Nonregulated Economics

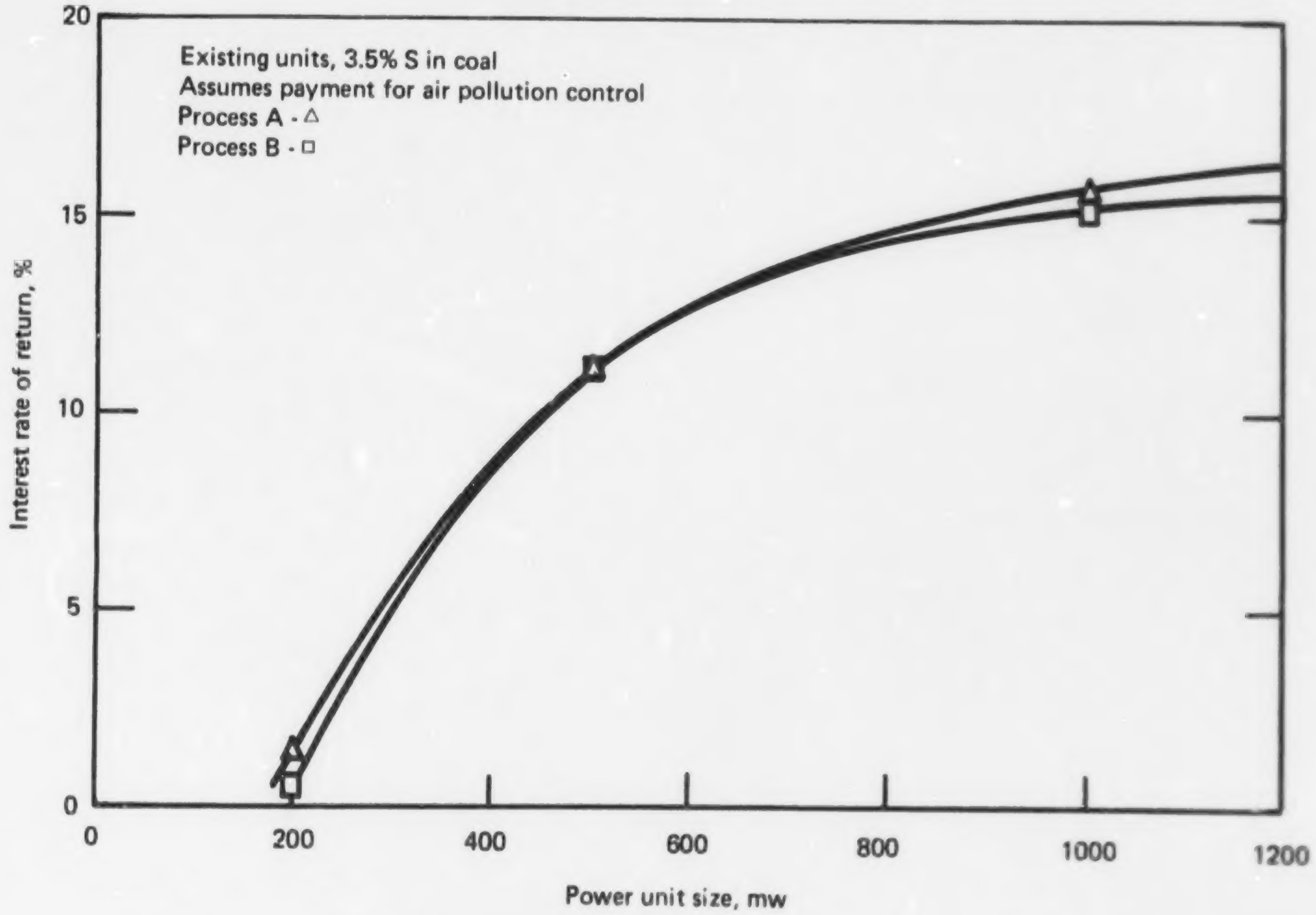


Figure 68. Effect of Power Unit Size on Interest Rate of Return for Nonregulated Economics

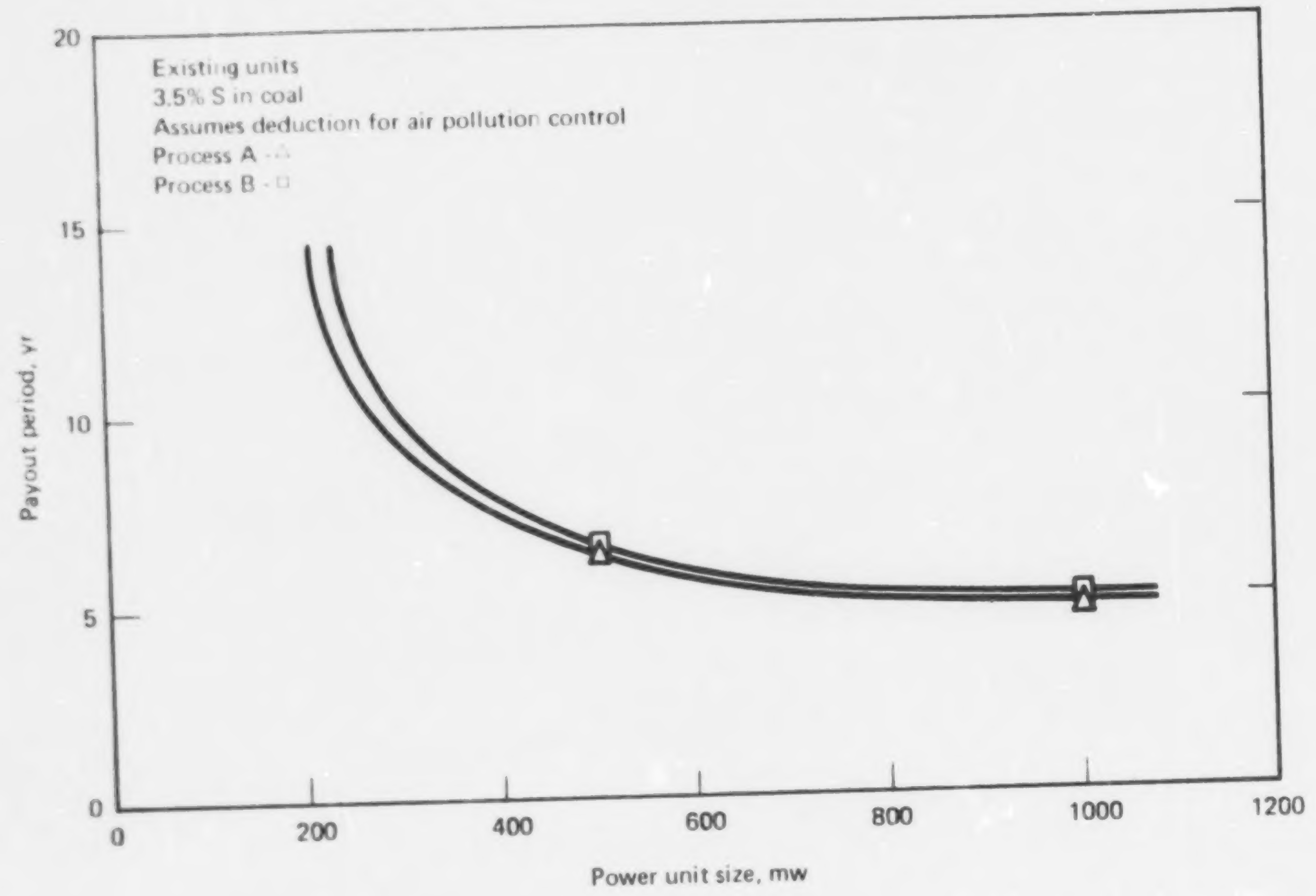


Figure 69. Effect of Power Unit Size on Payout Period for Cooperative Venture

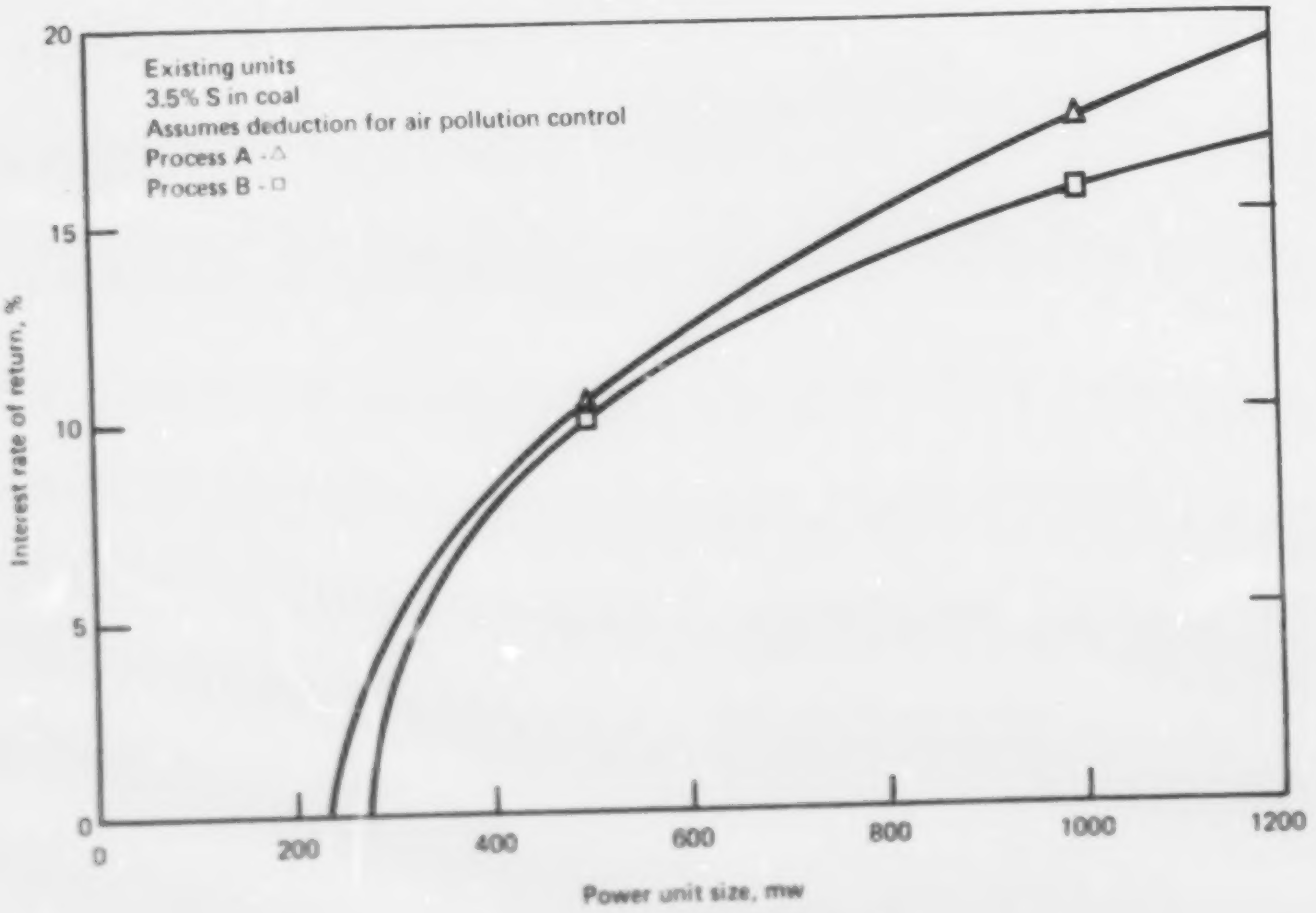


Figure 70. Effect of Power Unit Size on Interest Rate of Return for Cooperative Venture

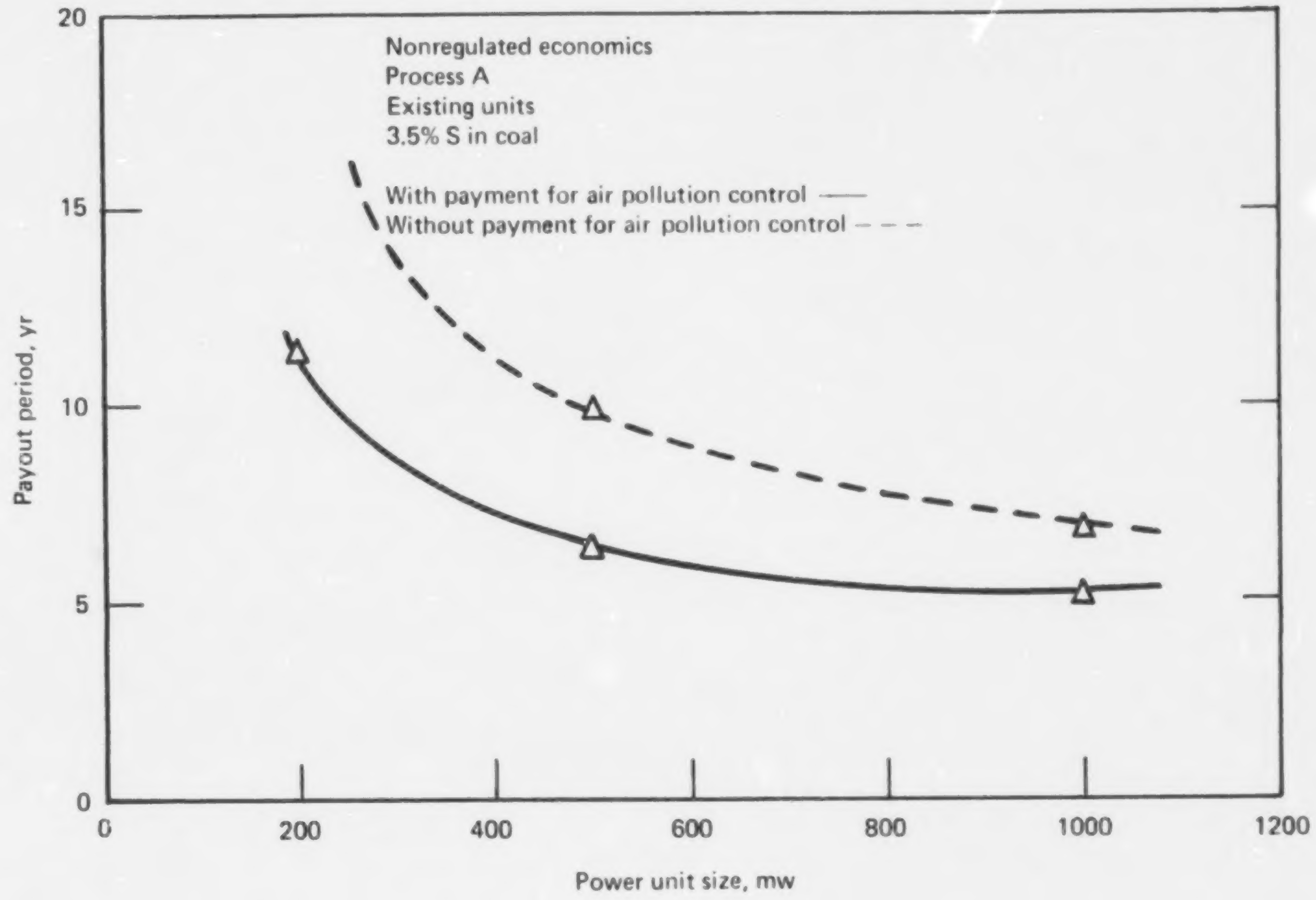


Figure 71. Effect of Credit for Air Pollution Control on Payout Period

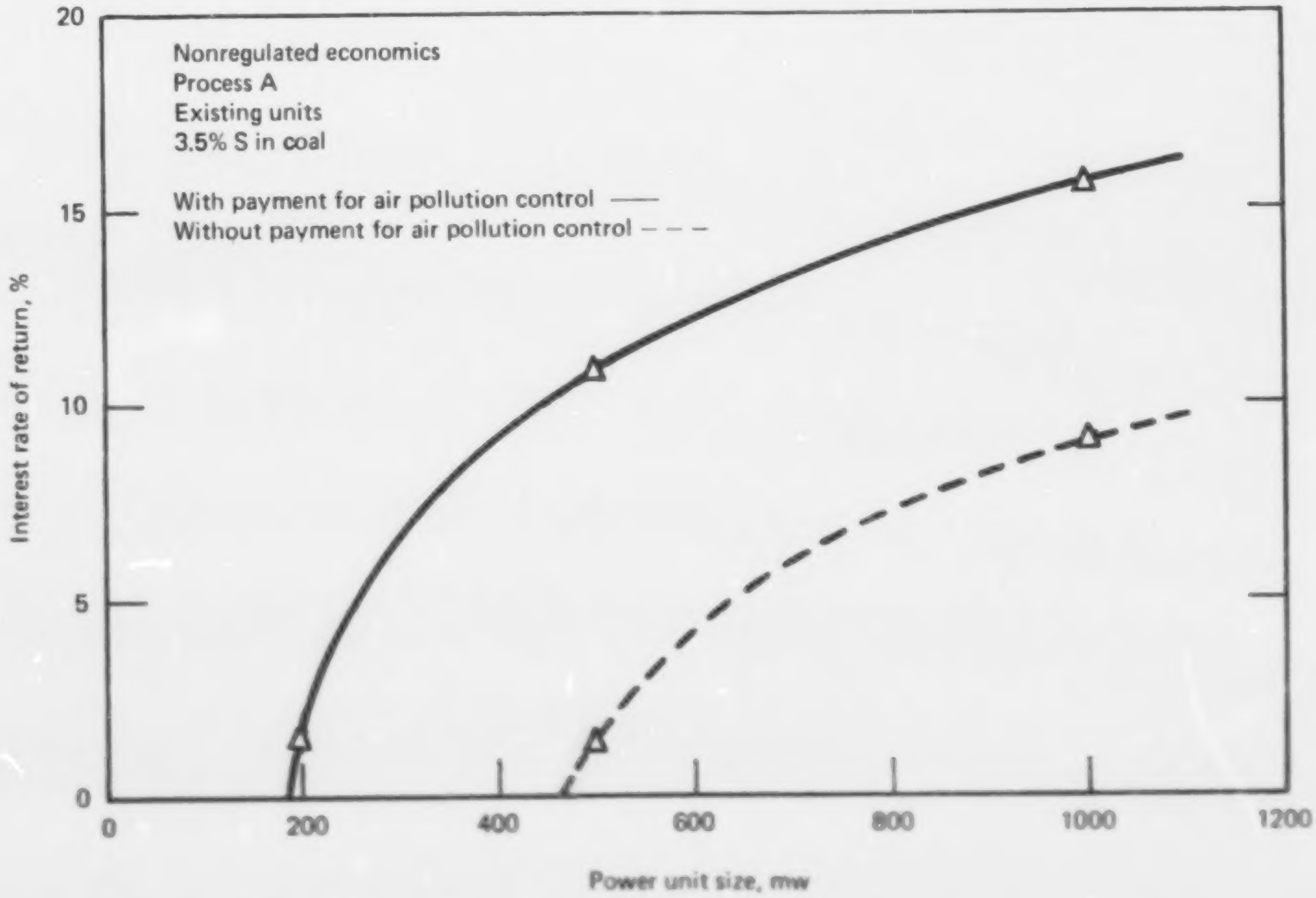


Figure 72. Effect of Credit for Air Pollution Control on Interest Rate of Return

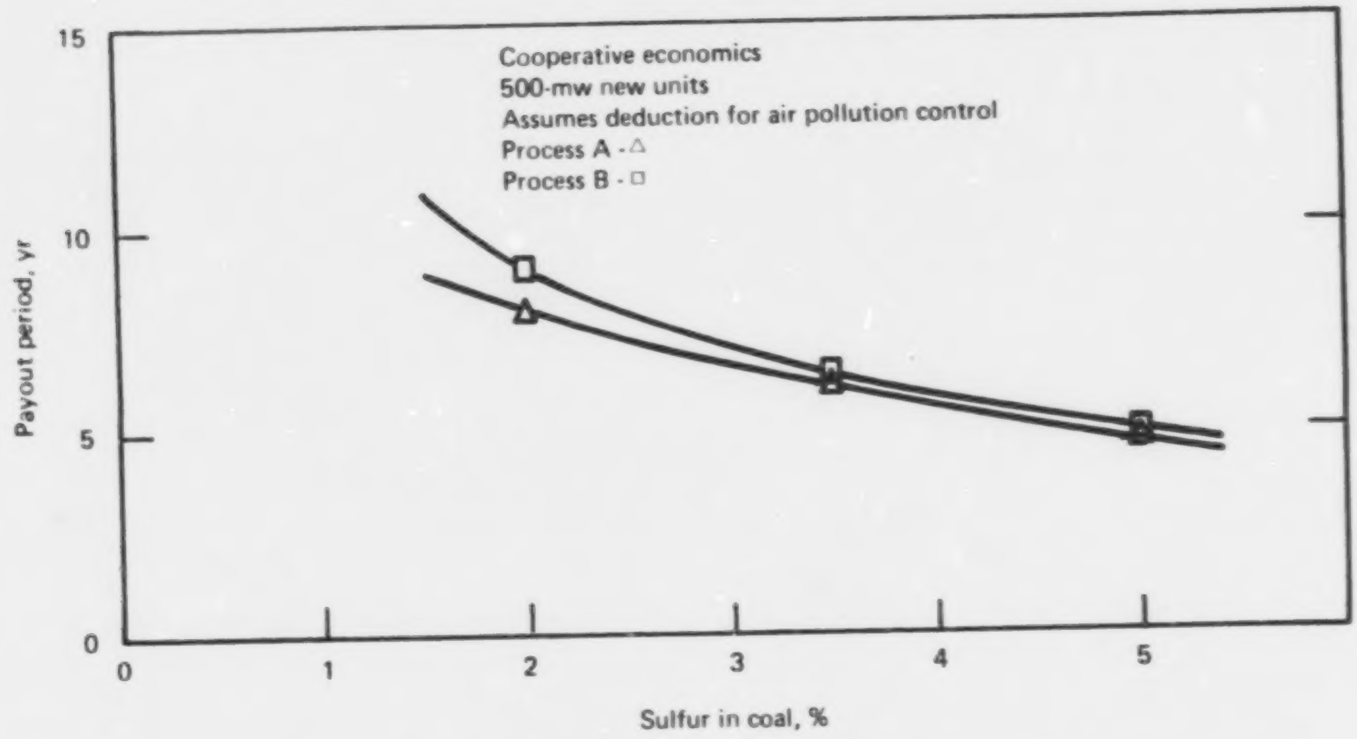


Figure 73. Effect of Sulfur Content of Coal on Payout Period

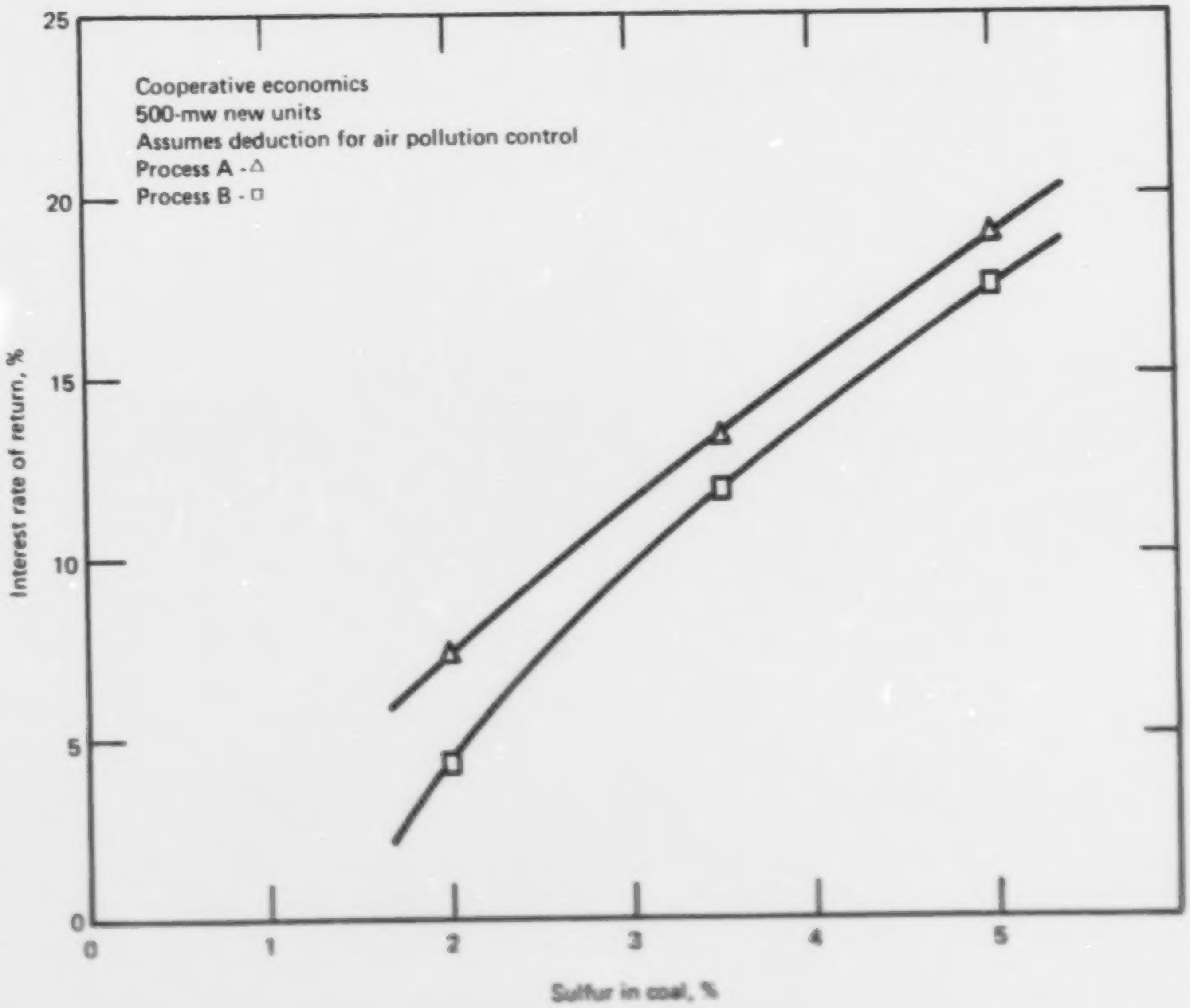


Figure 74. Effect of Sulfur Content of Coal on Interest Rate of Return

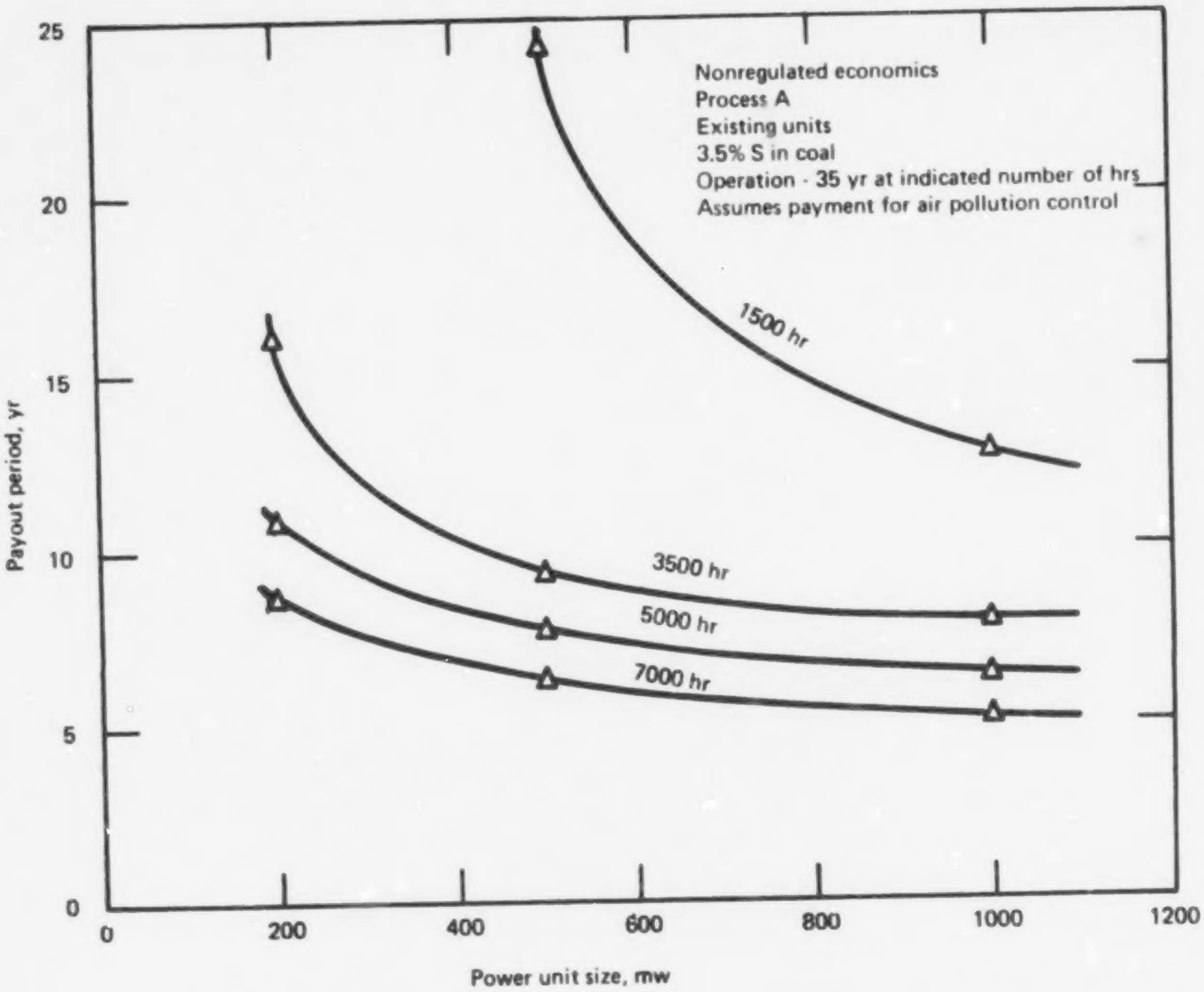


Figure 75. Effect of Operating Time on Payout Period

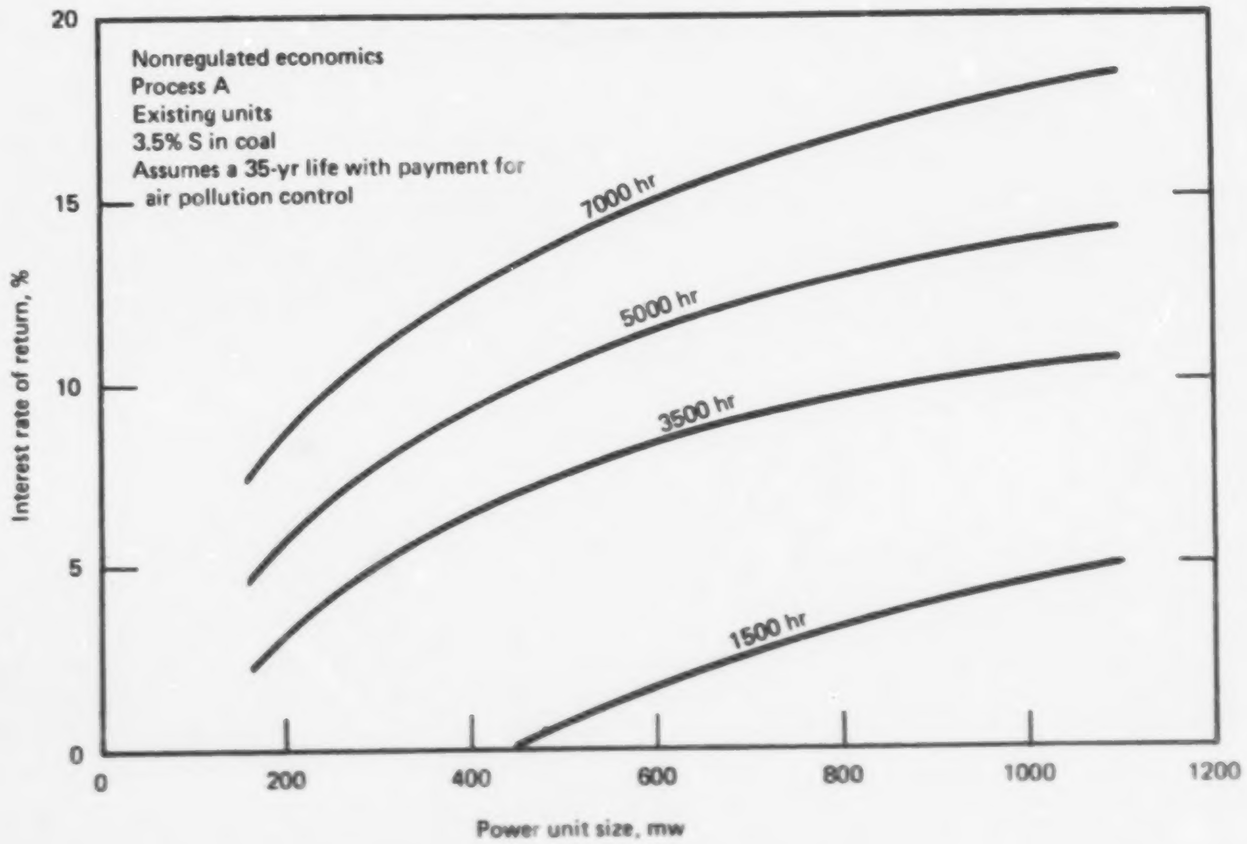


Figure 76. Effect of Operating Time on Interest Rate of Return

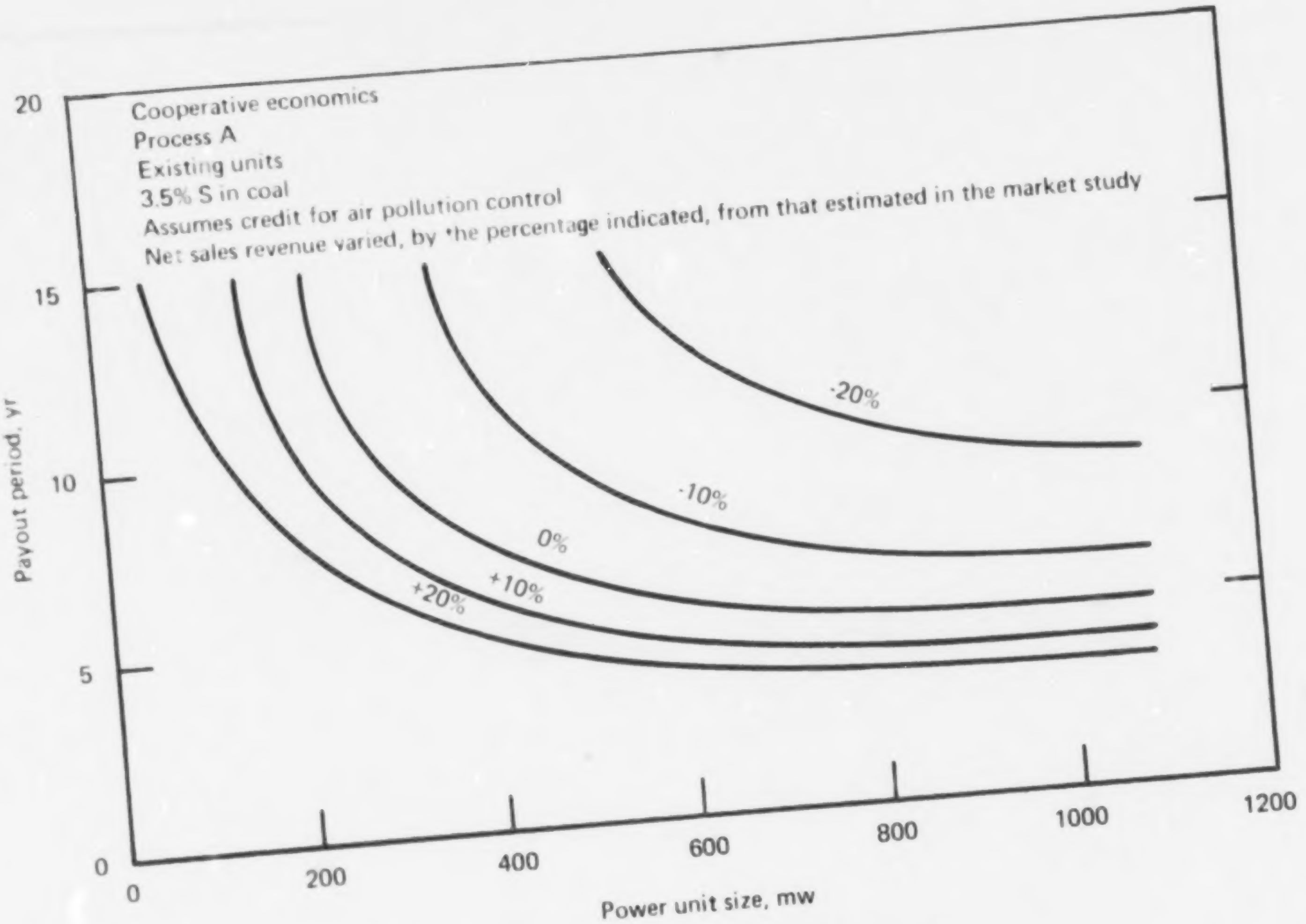


Figure 77. Effect of Variations in Net Sales Revenue on Payout Period (Process A)

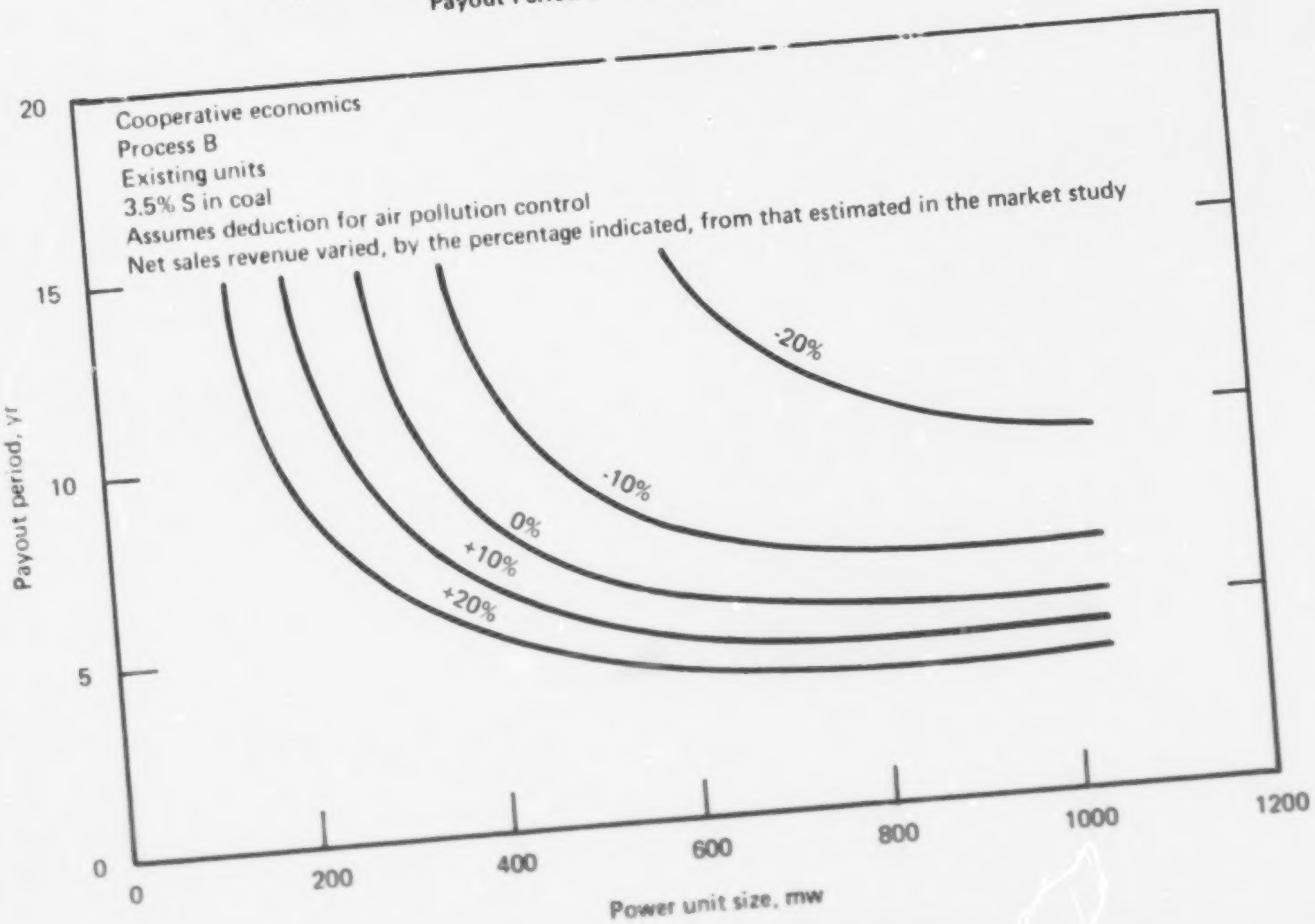
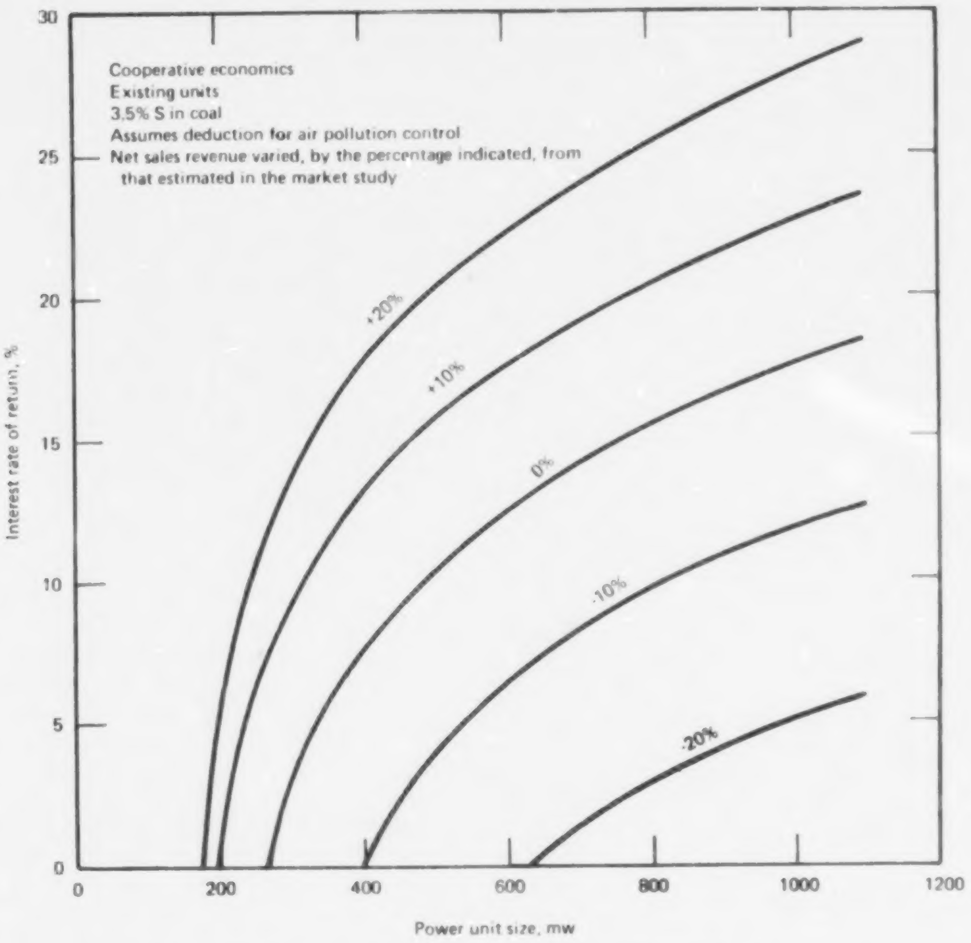
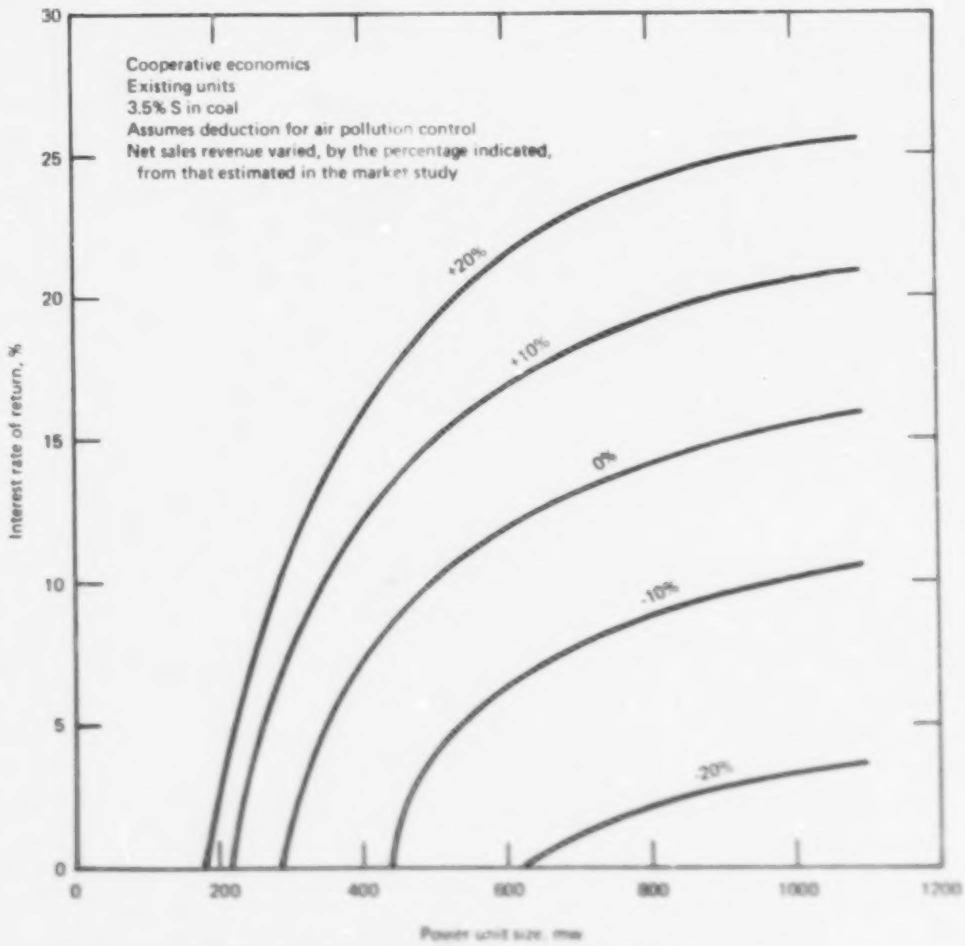


Figure 78. Effect of Variations in Net Sales Revenue on Payout Period (Process B)



Cooperative economics
Existing units
3.5% S in coal
Assumes deduction for air pollution control
Net sales revenue varied, by the percentage indicated, from that estimated in the market study

Figure 79. Effect of Variation in Net Sales Revenue on Interest Rate of Return (Process A)



Cooperative economics
Existing units
3.5% S in coal
Assumes deduction for air pollution control
Net sales revenue varied, by the percentage indicated, from that estimated in the market study

Figure 80. Effect of Variation in Net Sales Revenue on Interest Rate of Return (Process B)

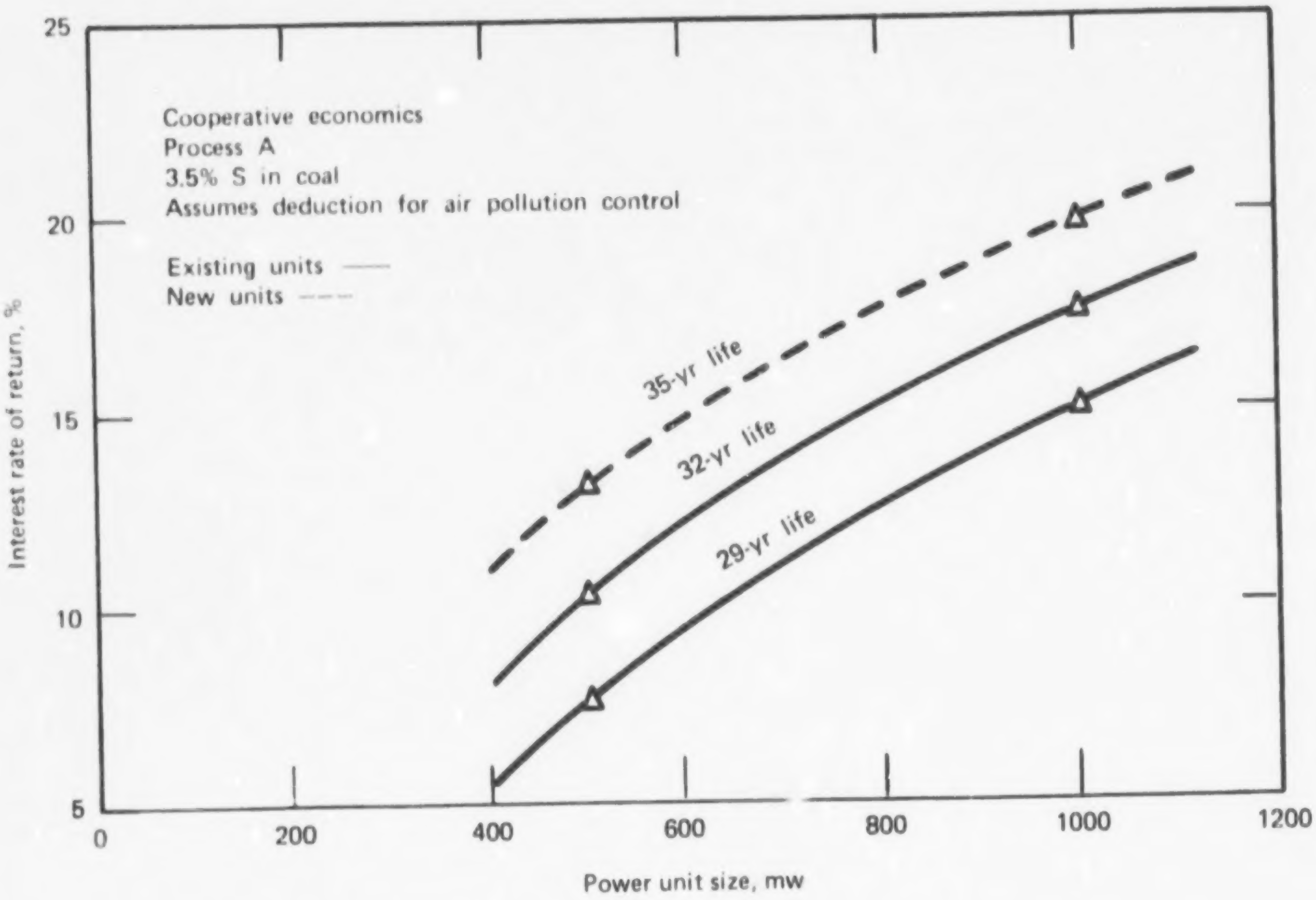


Figure 81. Effect of Recovery Unit Life on Interest Rate of Return

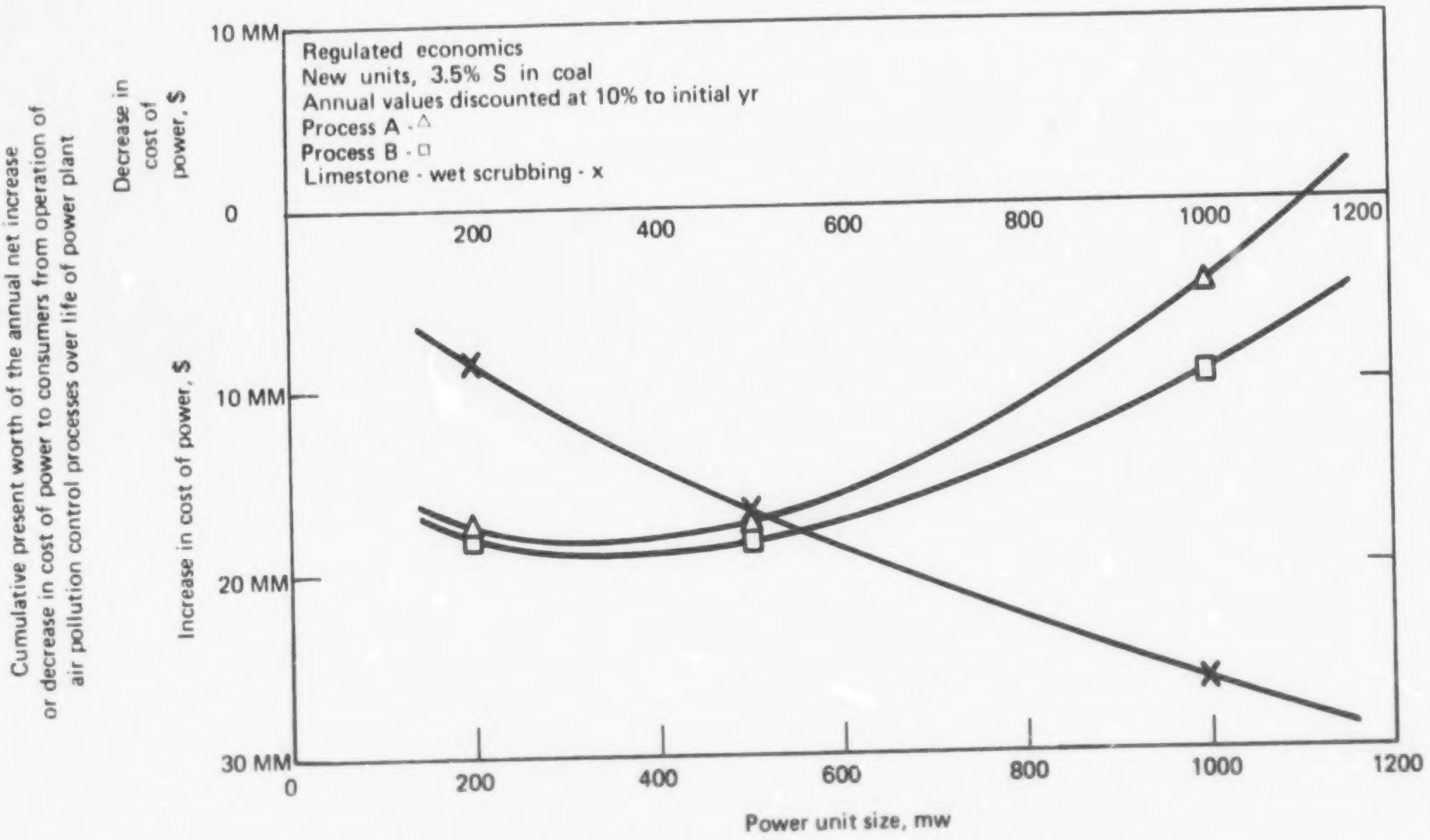


Figure 82. Effect of Power Unit Size on Cumulative Present Worth of Annual Net Increase or Decrease in Cost of Power Consumers

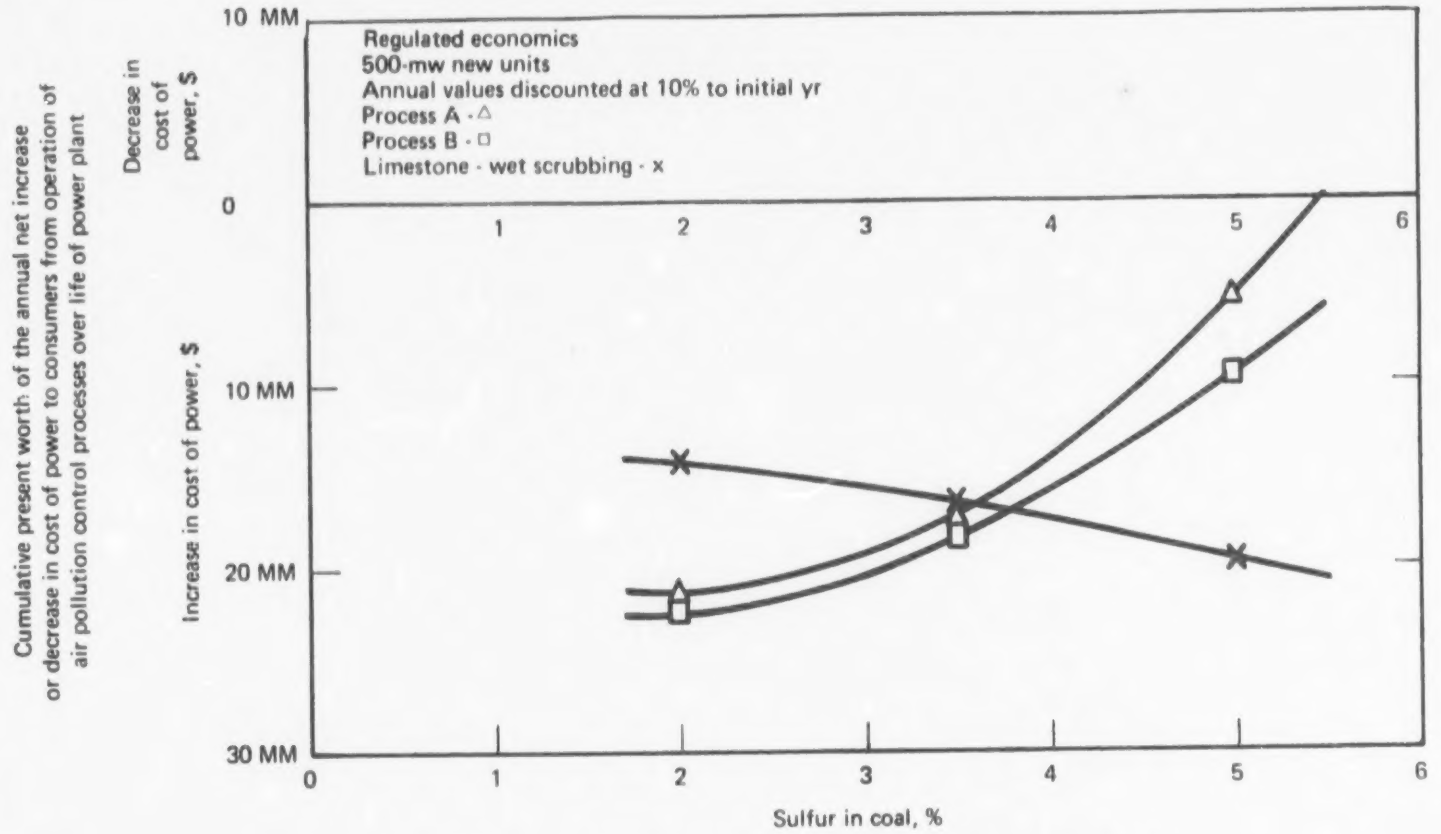


Figure 83. Effect of Sulfur Content of Coal on Cumulative Present Worth of Annual Net Increase or Decrease in Cost of Power to Consumers

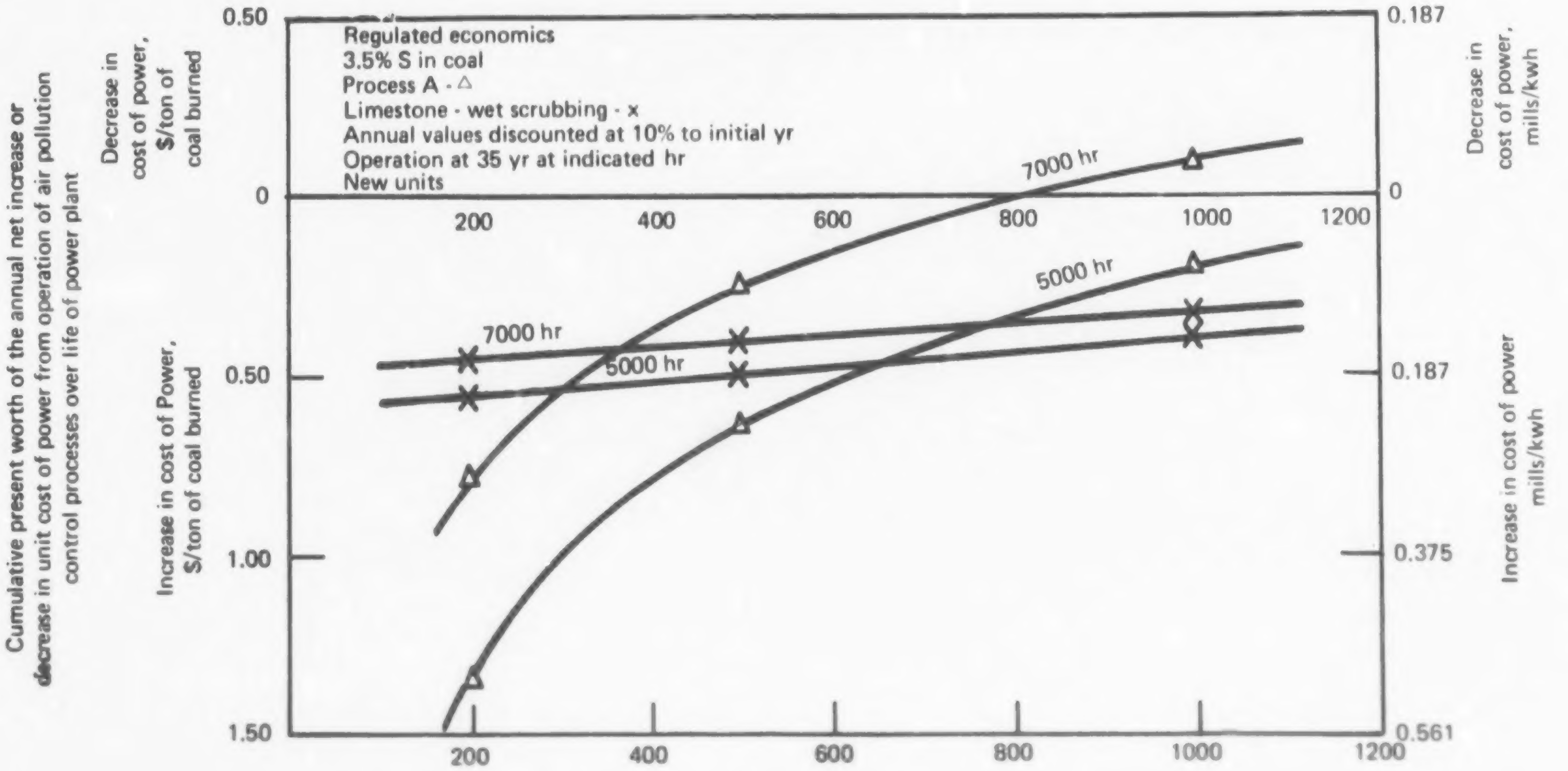


Figure 84. Effect of Operating Time on Present Worth of the Cumulative Net Increase or Decrease in Cost of Power to Consumers

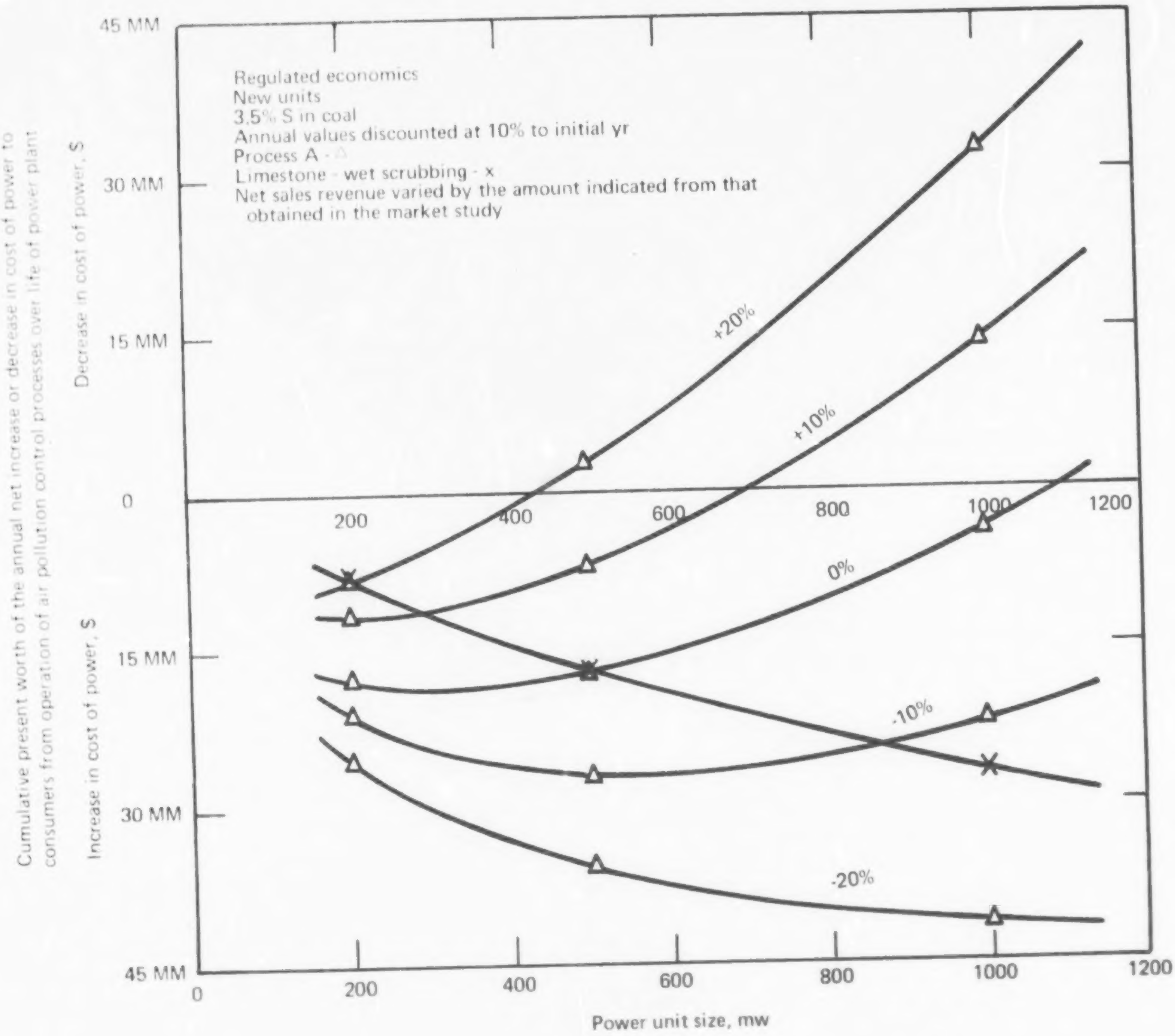


Figure 85. Effect of Variation in Net Sales Revenue on Cumulative Present Worth of the Annual Net Increase or Decrease in Cost of Power to Consumers (Process A)

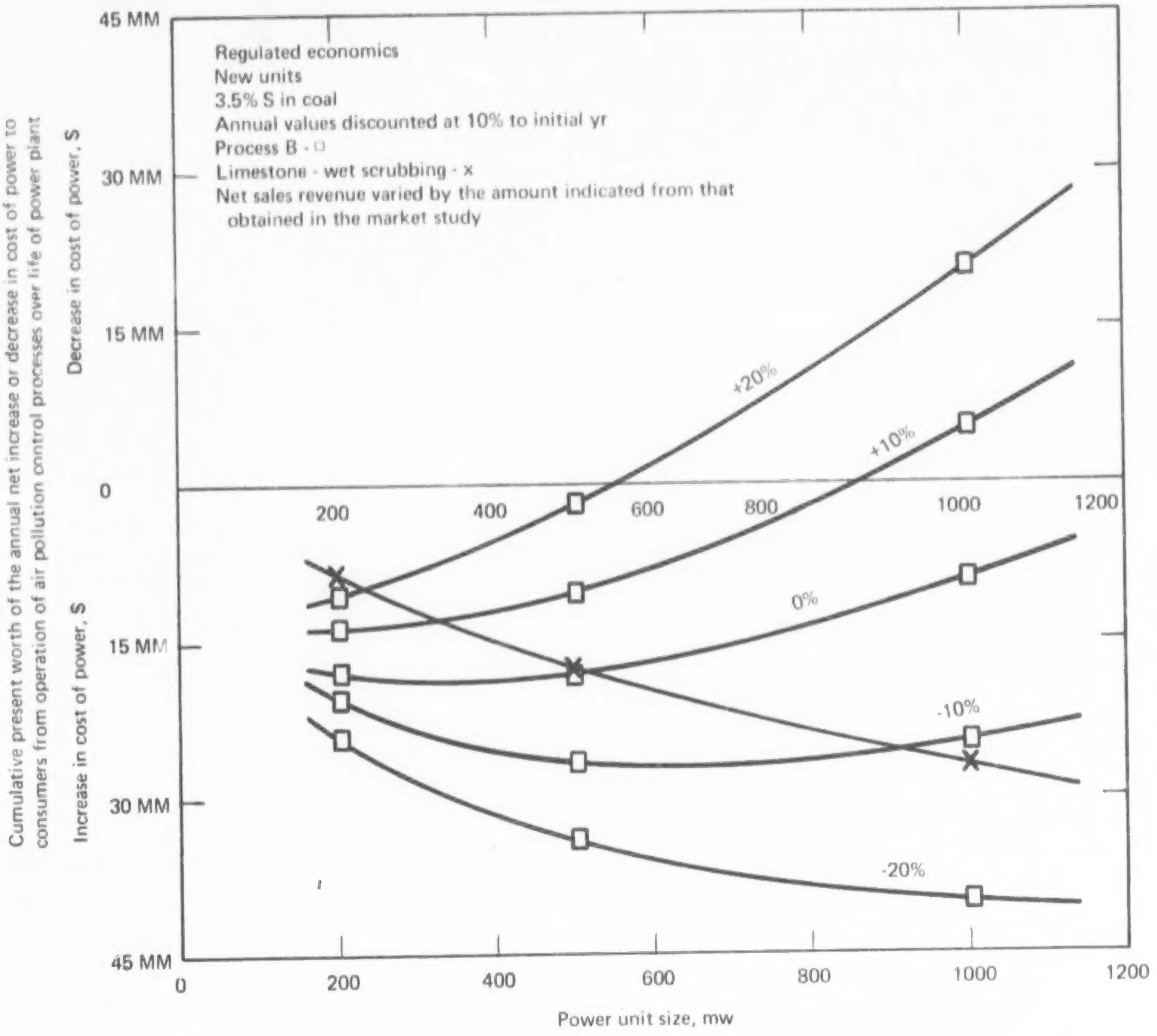


Figure 86. Effect of Variation in Net Sales Revenue on Cumulative Present Worth of the Annual Net Increase or Decrease in Cost of Power to Consumers (Process B)

RESEARCH AND DEVELOPMENT NEEDED

As would be expected in a conceptual design study, confidence level is reduced by lack of complete design and cost data. Further information is needed on several variables to improve the assumptions made in the present evaluation. Much of this is in process of development in the current pilot plant study being carried out by TVA for NAPCA on the scrubbing step; this study will provide data on sulfite oxidation, dust removal, control of scrubber liquor composition, and corrosion. In addition, the need for further research on treatment of the scrubber effluent solution should be considered. All the research needs, both for the scrubbing and effluent treatment operations, are listed for reference as follows.

Many of the variables involved in ammonia scrubbing have been tested previously by other investigators. However, some of the published data are conflicting and many studies were carried out under process conditions that do not appear applicable (for example, cooling the gas to well below the wet bulb temperature). Therefore, it is considered that further study is necessary.

Degree of Oxidation in Scrubber

In processes A and C (page 54), it was assumed that a separate processing step would be required to convert the ammonium sulfite-bisulfite in the scrubber effluent solution to ammonium sulfate. If the oxidation could be accomplished in the scrubber circuit with oxygen contained in the boiler exhaust gas, the considerable investment and operating costs for the oxidizer system would be eliminated. Even if all the oxidation could not be carried out in the scrubber circuit, partial oxidation would help since it would reduce the size of the oxidizer section.

Pilot plant data should be obtained on the effect of all the variables that may effect oxidation rate, including scrubber design, scrubber material, fly ash content of scrubber liquor, addition of oxidation catalysts, development of thiosulfate in the scrubber liquor, amount of excess air in the boiler, concentration of solution in the last liquor scrubbing stages, and pH of the scrubber liquor. Adverse effects of such factors on scrubbing efficiency would have to be evaluated against the benefit of increased oxidation.

The possibility of crystallizing ammonium sulfate from a scrubber side stream as a means of avoiding a separate oxidizer should also be tested.

For process B (page 54), oxidation in the scrubber is undesirable because formation of sulfate reduces the net amount of sulfuric acid that can be produced. The oxidation studies described above should also provide information on methods for inhibiting oxidation in the scrubber.

Control of Bisulfite:Sulfite Ratio

In process B, the amount of sulfuric acid available for the fertilizer process depends on the ratio of bisulfite:sulfite in the scrubber liquor. Although much experimental work has been done on control of this ratio, data on operation with boiler exhaust gas in scrubbers of modern types are needed. Further information would be helpful, for example, on the effect of number of stages, pH and concentration in each stage, and liquor rates.

In contrast, bisulfite should be minimized for processes A and C in order to take advantage of any increase in scrubbing efficiency obtainable by use of high sulfite:bisulfite ratio.

Dust Removal

The degree of dust removal desirable before the sulfur dioxide scrubber depends both on effect of the dust on oxidation and effect on the phosphate fertilizer process. Tests on dust content of solutions in process A indicated that up to 25% of the dust could be tolerated in the phosphate process. Presumably this would be true also for process B but confirming laboratory tests should be made. As to process C, the economics may not be promising enough to warrant further tests.

For existing plants already equipped with dust-removal facilities, it has been assumed that no special wet-scrubbing section would be needed for dust removal. In some plants, however, the dust-removal efficiency of the dry collection units is not as high as desirable so this load would be thrown on the ammonia scrubbing system, which brings in the problem of efficiently removing the finer dust particles in a scrubber designed primarily for sulfur oxide absorption. Pilot scale or larger tests to determine the optimum scrubber type for both functions are needed.

Composition of Scrubber Liquor at Steady State

For the operating modes assumed in the present study, all the processes considered are once-through in regard to the scrubber circuit, that is, the operation is not the closed-loop type and there is no recycle from the scrubber effluent treatment steps. Therefore, dissolved solids would not be expected to accumulate in the scrubber liquor except to the extent that recycle rate in the scrubber circuit is larger than product draw-off rate and therefore allows limited accumulation.

If the concept of crystallizing ammonium sulfate from a scrubber side stream is practical, however, the system would then be closed loop except to the extent mother liquor adhered to the crystals. In such case, studies would be needed on the effect of dissolved solids buildup in the liquor on scrubber operation and efficiency.

Corrosion

The equipment design in this study is based on providing resistant materials of construction to avoid high maintenance costs. If pH excursions could be eliminated through adequate process control, plain steel equipment probably could be used in most of the scrubber system and significant investment savings would result. Pilot plant data are needed to evaluate the possibility.

Optimization of Scrubber Operation

There are several further variables that obviously need study in optimizing the scrubbing step, including scrubber type, gas velocity, mist collector type, inlet gas temperature, and point of ammonia addition. In regard to the last of these, it was assumed in the present study that some ammonia would be introduced ahead of the heating coil (in the gas reheat loop) to prevent corrosion by sulfuric acid mist. It might also be advantageous to introduce all the ammonia feed ahead of the scrubber. It has been claimed [by Kuhlmann (France)] that this converts most of the sulfur oxides to solid particles of ammonium sulfite and that collection of the solid particles in the scrubber is relatively easy—a particulate removal operation rather than gas absorption. This possibility should be tested.

Use of Ammonium Sulfate

The technology for use of ammonium sulfate in processes A and B is well defined. Decomposition of ammonium sulfate in process C to produce ammonium bisulfate and use of the bisulfate to digest phosphate ore are much less developed. Since the present study indicates that the economics of the method are not promising, there is some question as to whether any further research effort should be made. The main question is whether or not the relative lack of data unduly penalizes the process. Since the method is primarily a fertilizer process, it seems best to defer consideration in connection with the sulfur oxide recovery problem. If the fertilizer industry develops the method further and finds promise, it should then be considered again.

CONCLUSIONS AND RECOMMENDATIONS

In removing sulfur oxides from power plant stack gas, wet scrubbing has several advantages over dry absorption, including (1) better mass transfer, (2) easier absorbent circulation and handling, (3) less trouble with loss of absorbent in the gas stream leaving the system, (4) no problem with physical deterioration of the absorbent. Disadvantages include (1) necessity of reheating the gas and (2) possibility of corrosion. However, the cost of reheating is a relatively small part of the total cost and corrosion can be eliminated by proper choice of materials.

Of the various absorbents that can be used in a scrubber operation, alkali salts (ammonium, potassium, and sodium compounds) are especially effective because of their relatively high affinity for sulfur dioxide and the fact that both the absorbent and product are soluble, thereby avoiding the problems associated with using slurries. Ammonia has some advantage over the other alkalis because of its low cost. Moreover, the ammonia can be allowed to pass on into the product and sold at a price higher than initial cost, thereby avoiding problems in recycling the absorbent. Sodium has little or no value in the product and although potassium has fertilizer value the initial cost of the type of compound required (potassium carbonate or potassium hydroxide) is too high to make transfer to the product economically feasible.

Scrubbing with ammonia gives a solution of ammonium sulfite, ammonium bisulfite, and ammonium sulfate. There are many ways of converting this solution to a salable product. One of the more promising is conversion of the sulfites to ammonium sulfate and use of the ammonium sulfate in making a phosphate fertilizer. There are also variations of this approach.

Process A—Direct oxidation of the sulfites to ammonium sulfate and use of the resulting ammonium sulfate solution to precipitate calcium in a nitric phosphate process.

Process B—Acidification of the scrubber effluent with sulfuric acid to evolve sulfur dioxide and convert the ammonia to ammonium sulfate. The sulfur dioxide is converted to sulfuric acid, part of which is used for the acidification and the remainder, along with the ammonium sulfate, in the nitric phosphate process.

Process C—Ammonium sulfate is obtained as in process A above and is then converted to ammonium bisulfate by heating. The bisulfate, which is quite acidic, is reacted with phosphate rock (phosphate ore) and the acidulate further ammoniated to give ammonium phosphate.

The present study indicates that process A has a slightly better economic potential than process B and that both are markedly superior to process C. In fact, process C shows little economic promise under any of the combinations of conditions evaluated, mainly because of relatively high investment and low production volume.

It should be noted in regard to process C that process data were scanty as compared with the other methods. It may be that the indices assumed were too conservative, and that further research and development would develop more promise. This is primarily a matter for the fertilizer industry, however, for the process can be carried out without use of ammonium sulfate from a power plant. If the process is considered by the fertilizer industry to have promise, and if further development indicates it can compete with established phosphate processes, then it should be considered again for use in conjunction with ammonia scrubbing of power plant stack gas.

Investment for the entire operation—scrubbing, conversion of sulfite to sulfate, and fertilizer production—is relatively high because a finished product is made rather than an intermediate such as sulfur or sulfuric acid; a major portion of the investment—about 75%—is in the fertilizer plant. Total investment ranges from $26.60-44.60/kw, depending on plant size and process type; in comparison, investment for limestone - wet scrubbing varies from $8.20-13.10 for the same plant sizes. If the recovery system is installed at the same time the power plant is built, some reduction in investment is obtained because the precipitator can be eliminated. The resulting range, after credit for the precipitator, is $23.10-41.10/kw.

The high investment makes capital charges an important part of total operating cost and consequently the method of assessing capital charges has a major effect on process profitability. Project financing was evaluated on three different bases.

1. All investment by a fertilizer company.
2. Cooperative venture in which the power company would finance the scrubbing and oxidation portions and the fertilizer company would build the fertilizer plant only.
3. All investment by the power company.

Since the power company investment presumably would be incorporated into the rate base, depreciation is considerably less than that usual in the unregulated fertilizer industry; the annual rates assumed were 2.85 and 10%, respectively. Other items also differ, giving total capital charges of 6.5% for power company operation (not including interest, return on equity, or income tax) and 12% for the fertilizer company.

The estimated operating costs vary not only because of difference in capital charges among the financing bases assumed but also because the three processes make different types of fertilizer and different amounts/unit of power production. Hence the only valid comparisons are those concerned with cash flow (net income plus depreciation) per unit of investment. As a matter of perspective, however, it is of interest to note that overall operating cost/ton of coal burned ranges from $4.57-11.97, as compared with $1.46-1.80 for limestone - wet scrubbing (average over life of the power plant, for which average operating factor is relatively low). This indicates the magnitude of the revenue that must be obtained from sale of product to offset operating cost.

The price obtainable for the product varies with product type (ratio and concentration of plant nutrients) and pricing strategy (competitive products aimed at in marketing). Net revenue is also affected by product volume (larger tonnage requires larger sales area and consequent higher freight cost). For a plant located in the Midwest, the most favorable location, the best market strategy appears to be pricing for competition with ammonium nitrate. Prices obtainable on this basis are estimated at $42.79-55.09/ton of fertilizer. The netback price (return to manufacturing) ranges from $33.40-46.30/ton.

Another finding in the market study is that not more than about three 500-mw plants using process A could be accommodated in the midwestern part of the country under the marketing strategy assumed. Several more would be feasible, perhaps up to 10, if the product price were lowered to allow competition with diammonium phosphate. However, the price reduction required, about $9/ton of 28-14-0 product, would have a drastic adverse effect on economics. Fertilizer markets in other parts of the country might support a few more scattered 500-mw-size recovery plants but profitability would be poorer than in the midwestern area.

Profitability based on the estimated market prices (for ammonium nitrate competition) is affected by several factors, including (1) plant size, (2) sulfur content of coal, (3) average operating factor over the life of the power plant, and (4) power plant status (new or existing at the time of recovery unit installation). The sensitivity of economic promise (expressed as projected interest rate of return, which takes into account the time value of money) to these factors is illustrated by the following.

	Change in factor		Percentage increase in interest rate of return, %
	From	To	
Plant size, mw	500	1,000	110
Sulfur content of coal, %	3.5	5.0	100
Status	Existing	New	30
Operating factor, hr/yr	5,000	7,000	36

These figures are only typical, of course, as the effects are interdependent; the magnitude of each depends on the level of the other factors.

It is concluded that plants of 200-mw equivalent size do not break even (in the sense of lifetime net income exceeding costs) under any circumstances. Most of the 500-mw combinations (for processes A and B) do better than break even but do not generate enough profit to pay a return on equity capital sufficient to attract investment. This is true for both the all-fertilizer and the cooperative ventures (no major difference between the two).

Under a few extreme combinations of conditions, the cash flow may be sufficient to make the venture attractive enough to generate the necessary capital. For example, a new 500-mw unit burning coal containing 5.0% sulfur pays out the investment in 6.6 yr and gives an 11.4% interest rate of return; a new 1000-mw unit burning more typical coal (3.5% S) pays out in 6.4 yr at 12.0% interest rate of return (both for process A). These profit levels might be acceptably high under some circumstances but they appear to be lower than average. There is no set level, of course, below which a company turns down a venture because of lack of promise; much depends on the situation. A payout of 5 yr and an interest rate of return of 15% seem to be reasonable rough averages for minimum levels required in industrial practice. At the current high interest rates, a shorter payout and higher interest rate of return may well be necessary.

For an operation such as pollution abatement, there is always the possibility of accelerated depreciation being allowed, which is, in effect, a reduction in income tax in the early yrs of operation. No attempt has been made in the present study to make a detailed analysis of the effect of such acceleration. However, for the two examples given above, allowance of 5-yr depreciation would make the project pay out in about 5 yr—an attractive investment opportunity. In contrast, for a 500-mw new unit burning 3.5% sulfur coal, payout would require 7.7 yr even with the allowance of 5-yr depreciation; in this case, gross income is so relatively small that income tax is not a major cost factor.

It is concluded that even with accelerated depreciation, the basic economics are not very promising for fertilizer industry participation. The situation would be improved if the power producer paid to the fertilizer company a service charge for pollution abatement, or, if in a joint project the power company transferred the ammonium sulfate solution at a discount. The upper limit of such a payment or discount would be the cost of abating pollution by limestone - wet scrubbing.

On this basis, the prospect is much better although still not highly promising. For all-fertilizer operation and assuming payment by the power company of the full cost of limestone - wet scrubbing, a new 500-mw unit burning 3.5% sulfur coal (process A) would pay out in 6.1 yr and give a 13.0% interest rate of return. For a 1000-mw unit on the same basis, the respective figures are 4.9 yr and 17.9%.

It is concluded that fertilizer industry participation in sulfur recovery, by the methods evaluated in the present study, is somewhat questionable from the economic standpoint. The relatively high investment required and the resulting high cash flow projection needed to attract capital are major obstacles. This does not rule out the possibility, however, that in some situations (probably limited in number) particular sets of conditions will be favorable enough to make project financing possible.

For power industry financing, the fact that profit is much less significant makes the economic approach quite different. The investment in recovery facilities presumably would be incorporated in the rate base, on which, in principle, a reasonable rate of return is allowed by the regulatory authority. The main question in regard to sulfur recovery is whether the net cost situation would be better or worse than for limestone - wet scrubbing, which currently appears to be the most economical alternate to recovery.

On this basis, all 200-mw installations considered in the present study would cost more to operate than for the limestone process. For the base case (500-mw, process A, new power plant, 3.5% S in coal), the two methods are almost a toss-up, one more costly during some yrs of the operating life and the reverse in other yrs. On a present worth basis (discounted at 10%), process A loses $17.2 million over the 35-yr life and lime scrubbing costs $16.9 million. All 1000-mw units, plus 500-mw with 5.0% sulfur in coal, show a major advantage for recovery for either process A or B.

Hence for power units of about 600 mw and larger in size, processes A and B can be considered as ways of reducing the cost of sulfur dioxide control and would be attractive ventures. With fertilizer industry participation, 1000-mw installations are required before the economics begin to justify the venture. This reflects the effect of regulated profits.

There are opportunities for improving the economics further. For example, if some way could be found to operate the recovery unit fairly uniformly rather than in accordance with the declining load factor of the power plant, a major advantage would be obtained. High-sulfur coal is also quite advantageous; higher sulfur content increases revenue much more than it increases operating cost.

The economics are quite sensitive to the price assumed for the product. Even a 10% increase over the price level assumed would bring units as small as 300 mw into consideration for recovery, and at about 800 mw there would even be the prospect of making enough profit to reduce the cost of power (after paying the usual return on investment allowed to the power industry). On the other hand, a 10% lower price level would increase the power unit critical size (breakeven between recovery and lime scrubbing) to about 850 mw. The estimate of future price was the best that could be developed but, like any such long-term estimate, it could well be off by 10% or more.

It should be noted that even under the best conditions, processes A and B will not be widely applicable. The fertilizer market can absorb the output from only a few 500- to 1000-mw installations.

Further research on the processes is needed, most of which is planned in the current NAPCA-TVA pilot plant program. In addition, the approach of eliminating the oxidizer by crystallizing ammonium sulfate from the scrubber liquor should be worth further study. Finally, design and cost studies should be carried out on other ways of treating the scrubber effluent solution, including acidification with nitric acid or phosphoric acid to make ammonium nitrate and ammonium phosphate, respectively. The latter might be especially promising if the evolved sulfur dioxide could be fed into a sulfur-burning sulfuric acid plant where the full amount of sulfuric acid needed for the phosphoric acid would be made, which should greatly reduce the cost of converting the sulfur dioxide to acid.

REFERENCES AND ABSTRACTS

1. Aerojet-General Corporation. "The Applicability of Aqueous Solutions to the Removal of SO_2 from Flue Gases." Special Report S-4850-01-1, 7 pp. (June 21, 1968) (unpublished).

   It was sought to determine whether CO_2 would replace SO_2 in an aqueous solution, and decrease the capacity of the solution for absorbing SO_2. Calcium or magnesium oxide slurries in excess of the amount of SO_2 present will absorb CO_2 and be converted into carbonates. There is a moderate possibility of precipitating calcium sulfite even in fairly dilute solutions.

2. Alabama Power Company. "New Process of Fertilizer Manufacture Announced." *Mfr. Rec.* 92(26), 53 (Dec. 29, 1927).

   A process for making ammonium phosphate is described. Phosphate rock is digested with a strong solution NH_4HSO_4 giving $CaSO_4$, H_3PO_4, and $(NH_4)_2SO_4$; excess NH_3 is added, precipitating $(NH_4)_3PO_4$ which is separated and converted by heat to diammonium phosphate. The $CaSO_4$ product is reconverted to ammonium sulfate by reaction with CO_2 and NH_3. Finally the ammonium sulfate is heated to 300° C with formation of NH_3 and NH_4HSO_4.

3. Andrianov, A. P., and Chertkov, B. A. "Ammonia Recycle Method for the Sulfur Dioxide Absorption Method from Flue Gases." *Khim. Prom.* 1954(7), 394-401.

   Flue gas is purified by cooling with water and neutralizing with NH_3.

4. Anonymous. "Smelters Poised for Move into Sulfur." *Can. Chem. Process.* 52(3), 63-65 (Mar. 1968).

   A special report is given on the plans of some Canadian ore processors to reclaim sulfur from smelting operations.

5. Bergwerksverband zur Verwertung von Schutzrechten der Kohlen technik GmbH (by A. Adelsberger, O. Grosskinsky, W. Klempt, and H. Umbach). "Ammonium Sulfate Recovery from Flue Gases." Ger. Pat. 962,253 (Apr. 18, 1957).

   SO_2 in flue gas is absorbed by NH_3-containing solutions, then oxidized. The ammonium sulfate formed is separated by evaporation. The NH_3 concentration of the absorbing liquid is 1.3-2.1 moles/mole SO_2. The ammonium sulfite solution is neutralized with NH_3, oxidized by air or O_2 in a tower, and the crystalline product contains 90% of the SO_2 of the flue gas.

6. Burgess, W. D. "SO_2 Recovery Process as Applied to Acid Plant Tail Gas." *Chem. Can.* (June 1956), 116, 118, 120.

   The Cominco process for recovering SO_2 from tail gas containing 1% SO_2 is described. The gas is collected in a flue, discharged into a tower where it is scrubbed with ammonium sulfite-bisulfite solution; NH_3 is added to maintain the concentrations; the mixture is discharged into a tower, 93% H_2SO_4 is added yielding SO_2 and converting the solution to ammonium sulfate. The ammonium sulfate is saturated with SO_2 so this is stripped. The ratio is ammonium sulfate 56 parts to SO_2 44 parts.

7. Chertkov, B. A., Aristov, G. E., and Puklina, D. L. "Absorption of Sulfur Dioxide from Flue Gas in a Bubble-Type Absorber." *Khim. Prom.* 1956, 19-25.

   The process was studied in the laboratory with 4-6 perforated plates, hole diameter 4-5 mm. With 6 plates, linear gas velocity 2.4 m/sec, total bubbler resistance 150-200 mm water, temperature 30-33°, 90% of the SO_2 can be extracted, and the absorbing ammonium sulfite-bisulfite becomes saturated. Foaming depends on gas velocities, and occurs only in a narrow range. Absorption rate is 10-20 times the rate in a checkerwork absorber.

8. Chertkov, B. A. "Oxidation of Ammonium Sulfite-Bisulfite Solutions." *J. Appl. Chem. USSR* 30(10), 1564-72 (1957).

   Ammonium bisulfite is oxidized preferentially. In the range of ammonium bisulfite content 63-100%, which is the range of practical importance, the oxidation rate of the solution increases sixfold. If free H_2SO_3 is present in addition to ammonium bisulfite, the oxidation rate decreases to complete cessation of oxidation, because of the sharp decrease in pH. Solution concentration has a complex influence on the oxidation rate; it depends on the rate of access of oxygen from the air. At a concentration of sulfite and bisulfite in the range of 2-3 moles/l, the oxidation rate is maximum, and it is at a minimum at very concentrated and very dilute concentrations.

9. Chertkov, B. A. "Kinetics of Absorption of SO_2 from Dilute Gaseous Mixtures." *Vestn. Tekhn. i Ekon. Inform., Mezhotrasl. Lab. Tekhn.-Ekono. Issled. i Nauchn.-Tekhn. Inform., Nauchn.-Issled. Fiz.-Khim. Inst.* 1958(5), 7-9.

   The rate of absorption of SO_2 was controlled mainly by the resistance of the gaseous boundary film. The study was made in a packed absorber of 0.6 m diameter. The more concentrated solutions had greater capacity. For each original SO_2 concentration, the optimum concentration of NH_4 salts and S/C ratio must be selected; 10-12 moles NH_3/100 moles H_2O and S/C ratio = 0.93-0.95 are used for 0.3-0.4% SO_2.

In the regeneration solution the $SO_2:NH_3$ must be 0.78-0.8 at 400-700 mm Hg pressure.

10. Chertkov, B. A., Puklina, D. L., and Pekareva, T. I. "The pH Values of Ammonium Sulfite-Bisulfite Solutions." *J. Appl. Chem. USSR* 32(6), 1417-19 (1959).

A study was made of the pH over the range of 0.5-1.2, ratios of $SO_2:NH_3$. Determination of the pH of the solution is considered a simple, dependable means of determining approximate compositions, instead of resorting to complex chemical analyses.

11. Chertkov, B. A. "The Influence of SO_2 Concentration in a Gas on Its Rate of Absorption by Different Solvents." *Khim. Prom.* 1959(7), 586-91.

The mass transfer coefficient remains constant during the variation of the initial SO_2 concentration from 0.08 to 3.5% by volume. At higher initial SO_2 concentrations, a constant decrease of the coefficient is observed.

12. Chertkov, B. A. "Removal of SO_2 from Flue Gases in a Perforated Plate Bubble Absorber." *Khim. Prom.* 1959(5), 413-17.

In a six-stage bubble absorber at optimum conditions the average coefficient of absorption of SO_2 is 21 kg SO_2/m^3 x hr x mm Hg, which is 13 times higher than in a packed column absorber. The fly ash is collected in the first two or three stages.

13. Chertkov, B. A. "Theory of the Oxidation of Sulfite-Bisulfite Solutions." *J. Appl. Chem. USSR* 32(12), 2687-90 (1959).

An explanation is given for the so-called "catalytic" role played by thiosulfate in the general mechanism for the oxidation of sulfite-bisulfite solutions, which is supported by experimental results. The presence of thiosulfate as impurity is due mainly to the spontaneous decomposition of the thermodynamically unstable bisulfite. The catalytic action exerted by the thiosulfate is linked with its participation in the continuous thiosulfate-trithionate conversion, facilitating the more rapid oxidation of the sulfite-bisulfite solution.

14. Chertkov, B. A. "Effects of Temperature and Partial Pressure of Oxygen in the Gas on the Oxidation Rate of Ammonium Sulfite-Bisulfite Solutions." *J. Appl. Chem. USSR* 32(1), 78-85 (1959).

An empirical relation was derived which can be used for the estimation of the oxidation rate of the solution at any given temperature if the oxidation rate of the solution at any other temperature is known. Increasing O_2 partial pressure in the gas increases the oxidation in the solution.

15. Chertkov, B. A. "Use of Paraphenylenediamine as Oxidation Inhibitor for Ammonium Sulfite-Bisulfite Solutions." *J. Appl. Chem. USSR* 32(5), 975-82 (1959).

It is most effective as an oxidation inhibitor when added to pure solutions, not contaminated with solid impurities. When ash from flue gases is present, for example, the efficiency is reduced three to four-fold. The inhibitor effect is evident both under static conditions and in a cyclic process in the extraction of SO_2 from flue gases.

16. Chertkov, B. A. "Oxidation of Ammonium Sulfite-Bisulfite Solutions in the Extraction of SO_2 from Flue Gases." *J. Appl. Chem. USSR* 32(5), 983-87 (1959).

Practical data on the oxidation in packed absorbers is analyzed. The degree of oxidation of the absorbed SO_2 can be lowered considerably if the absorption is effected in a bubbler absorber operated under foam conditions.

17. Chertkov, B. A., and Puklina, D. L. "Effect of Temperature on the Rate of SO_2 Absorption from Gases." *J. Appl. Chem. USSR* 33(1), 7-10 (1960).

Laboratory experiments were conducted to obtain data of effects of temperature change alone on the rate of SO_2 absorption. Temperature had a strong effect especially on saturated solutions with a ratio $SO_2:NH_3$ = 0.936. The mass transfer coefficient fell from 10 to 2 moles/m² x hr x % SO_2 over the range 23-52° C. The strong effects are ascribed to the strong increase of equilibrium SO_2 vapor pressure with temperature increase, and also with increase in the $SO_2:NH_3$ ratio.

18. Chertkov, B. A. "Influence of Absorbent Composition on the Rate of Absorption of SO_2 from Gases." *Khim. Prom.* 1960, 223-27.

The coefficient of mass transfer K is not constant, but depends on the free chemical capacity and viscosity of the absorbent.

19. Chertkov, B. A. "Mass Transfer Coefficient for the Absorption of SO_2 in a Multistage Absorber." *Khim. Prom.* 1960, 559-62.

K, for gases containing 0.35-2.56% SO_2, is independent of the initial concentration of SO_2. In a six-stage absorber with gas velocities of 2-2.3 m/sec at room temperature, K = 1450 to 1970 moles/m² x hr x % SO_2, and 91.2% SO_2 was absorbed.

20. Chertkov, B. A. "General Equations for the Oxidation Rate of Sulfite-Bisulfite Solutions in the Extraction of SO_2 from Gases." *J. Appl. Chem. USSR* 34(4), 743-47 (1961).

Data on the oxidation kinetics under industrial conditions were correlated, and an empirical equation was derived for calculating the oxidation rates of various sulfite-bisulfite solutions used in extraction of SO_2 at low concentrations from gases.

$$\text{Oxidation rate } G_{O_2} = \frac{0.8\, Q^{0.7}\, a\, (S/C)^6}{\alpha \qquad \mu}$$

a = constant
Q = liquor rate $m^3/m^2/hr$
α = d
μ = viscosity

21. Chertkov, B. A., and Pekareva, T. I. "Density and Viscosity of Ammonium Sulfite, Ammonium Bisulfite, and Ammonium Sulfate Solutions." *J. Appl. Chem. USSR* 34(1), 135-41 (1961).

    The density and viscosity of $(NH_4)_2SO_3$-NH_4HSO_3 process liquors and artificial solutions were measured over a wide range of total salt concentration. The process liquors contained considerable amounts of $(NH_4)_2SO_4$ and small amounts of ammonium thiosulfate. The $SO_2:NH_3$ effective ratio was maintained roughly constant to correspond to the compositions of saturated and regenerated liquors in the cyclic NH_3 process for the extraction of SO_2.

22. Chertkov, B. A. "Problem of Using Waste Sulfurous Gases and Protecting the Atmosphere Against Pollutants." *Khim. Prom.* 1962, 336-38.

    The need for economical recovery of SO_2 on a large scale and possible uses of SO_2 are discussed.

23. Chertkov, B. A., and Dobromyslova, N. S. "The Influence of Traces of Sulfate on the Partial Pressure of SO_2 Over Ammonium Sulfite-Ammonium Bisulfite Solutions." *J. Appl. Chem. USSR* 37(8), 1707-11 (Aug. 1964).

    When the concentration of ammonium sulfate present is greater than the concentration of the sulfite-bisulfite, or in a dilute solution, or in processes in which the solutions obtained approach a state of equilibrium with the gas of a given concentration, the partial pressure of SO_2 over the solution may be affected seriously by changes in the concentration of ammonium sulfate.

24. Chertkov, B. A. "Coefficients of Mass Transfer in Absorption of SO_2 from Gases by Ammonium Sulfite-Bisulfite Solutions." *J. Appl. Chem. USSR* 37, 2404-10 (1964).

    Equations are given for the calculation of partial coefficients of mass transfer in the gas phase in absorbers of different dimensions for alkaline absorbents. The overall coefficient of mass transfer decreases with increasing saturation of the absorbent and with approach to equilibrium with the absorbed gas.

25. Colls, E. A. G. "Corrosion-Resistant Material and Coatings in Trail Chemical Operations." *Trans. AIME* 187, Mining Engineering, pp. 491-94 (Apr. 1950).

    Corrosion in the Trail plant is discussed. The most costly materials are cheaper in the long run. Steel towers lined with lead and acidproof brick are used for absorption of SO_2. Sulfite solution coolers have aluminum tubes. Ammonium sulfate is handled in 316 stainless steel. The cooler for SO_2 gas is cast iron.

26. Cominco Ltd. "The Story of Cominco." Chemical and Fertilizers Division, part 5, chap. 33-34. *Can. Mining J.* 75, 287-91 (May 1954).

    SO_2 recovery systems are discussed; concentrations of SO_2 in the gas are low; SO_2 is absorbed in ammonium sulfite (made from NH_3 and ammonium bisulfite); H_2SO_4 is added to the liquor giving ammonium sulfate and concentrated SO_2; products are ammonium sulfate and H_2SO_4. NH_3 is used to scrub all outlet gases.

27. Cominco Ltd. "Cominco's Fertilizer Operation." *Nitrogen* 35, 22-27, 29 (May 1965).

    A review is given of the large chemical and metallurgical production at Trail. The process for the recovery of ammonium sulfate and SO_2 by the acidulation of ammonium bisulfite solutions with H_2SO_4 is described.

28. Craxford, S. R., Poll, A., and Walker, W. J. S. "Recovery of Sulfate from Flue Gas by the Use of Ammonia." *J. Inst. Fuel* XXV(141), 13-14 (Jan. 1952).

    A description of the Simon-Carves and Fulham Borough plant for NH_3 scrubbing at a fuel research station is described. Exit gas contained 0.0005% SO_2, or 99% removal. The use of Mn catalyst was effective in promoting oxidation, but it was found that, after the equipment had corroded, the Fe oxide in the system was a good catalyst.

29. Earhart, J. P. (National Air Pollution Control Administration, U. S. Department of Health, Education, and Welfare, Cincinnati, Ohio). Private communication to C. C. Shale of the Morgantown Coal Research Center, May 5, 1969; enclosure entitled "Discussion of Gaseous Ammonia for Flue Gas Desulfurization," 19 pp.; copy of letter and enclosure received by A. V. Slack May 26, 1969.

    This is a critical review of the data in USBM RI 3339, with additional calculations on the thermodynamics of the system.

30. Egan, E. P., Jr. "Removal of SO_2 from Stack Gases." Tennessee Valley Authority Progress Report Assembly No. 47B, (Oct. 1955-Feb. 1968) (unpublished).

    Thermodynamic calculations were made of the removal of SO_2 from stack gases by the addition of NH_3 (one of a number of possible processes) into the gas at a point of favorable temperature to form solid ammonium sulfite. The stack gases usually contain 10-20 times as much CO_2 as SO_2, and it was necessary to determine whether the thermodynamics favored the reaction of NH_3 with SO_2 rather than CO_2.

31. English, G. E., and Van Winkle, M. "Efficiency of Fractionating Columns." *Chem. Eng.* 70(23), 241-44, 246 (Nov. 11, 1963).

A correlation equation was developed to give values for Murphee vapor plate efficiencies of fractionating columns. Experimental data and calculated properties were used. Variables having a definite effect on efficiency are weir height, contact area of vapor and liquid phases, relative vapor and liquid rate, surface tension, viscosity and density of the liquid, liquid diffusivity, and relative volatility.

32. Federal Power Commission. "Statistics of Privately Owned Electric Utilities in the United States." FPC S-186 (1966). Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402.

Composite statements are given for utility companies of class A (> 2.5 million dollars operating revenue) and class B (1.0-2.5 million dollars operating revenue). Historic tables for the last 30 yr, charts of most operations, balance sheets and other details are included.

33. Federal Power Commission. "Statistics of Publicly Owned Electric Utilities in the United States." FPC S-188 (1966). Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402.

The 560 publicly owned utilities (498 municipals and 62 Federal), for which financial and operating information is presented in this volume, reported total electric revenues of $2.2 billion for sales of 297 billion kwh to an average of 6.7 million customers during 1966.

34. Fedor, W. S. "Chemical Firms' Financial Performance Matches Other Industries'." *Chem. Eng. News* 46(21), 20-26 (May 13, 1968).

A financial analysis of 35 major chemical and allied products companies for 1963-1967, performed by a CEN computer, is presented.

35. Gardiner, R. A. "Process of Making a Mixed Phosphatic and Nitrogenous Fertilizer." U. S. Pat. 1,258,106 (Mar. 5, 1918). 2 pp.

Ground apatite was fused with ammonium sulfate; the temperature was increased to the decomposition of ammonium sulfate (about 400° C). Extraction of P was more complete if the apatite was ignited to 900° C before the reaction with ammonium sulfate.

36. Gordeev, L. S., and Chertkov, B. A. "Investigation of the Steady State Characteristics of a Process for Obtaining 100% SO_2 from Ammonium Bisulfite." *Int. Chem. Eng.* 7(4), 634-36 (Oct. 1967).

A study was made for optimizing an existing process for the recovery of SO_2 from ammonium bisulfite solutions. Liquid flow rate, boiling point, and S/C ratio are important variables. Aiming for the maximum possible plant efficiency is not advisable, since this leads to a sharp decrease in capacity and a deterioration of the quality of the spent solutions.

37. Gottfried, J., Nyult, J., and Hayerova, Z. "Research of the Phase Equilibrium in the Ammonium Sulfate-Ammonium Sulfite-Ammonium Bisulfite-Water System." *Chem. Prumysl* No. 3, 149-51 (1966).

The equilibrium was studied at 40, 50, 60, 70, 80, and 90° C. Synthetic solutions were prepared by saturating dilute aqueous NH_3 with gaseous SO_2. The concentration range of the solutions was $SO_2:NH_3$ = 0.9, 0.8, 0.7, 0.3. Solubility data were obtained. Phase diagrams are given. The solubility of ammonium sulfate was independent of the ratio ammonium sulfite:ammonium bisulfite.

38. Grigoryan, G. O., Karakhanyan, S. S., Mirumyan, R. L., and Makhtesyan, I. M. "Processing of Common Salt. VI–Decomposition of Apatite Concentrate by Ammonium Bisulfate with an Increase in Acid Normality and Establishment of Optimal Conditions for Filtration and Washing of the Resulting Filter Cake." *Arm. Khim. Zh.* 20(2), 157-63 (1967).

The highest decomposition (96-98%) and better filterability were obtained when 140-144 parts H_2SO_4 (as NH_4HSO_4) was used/100 parts apatite by wt (1 hr, at 98°); three stages of countercurrent washing were used.

39. Hamelin, R. (Ugine Kuhlmann, Paris, France). Private communication, May 1969.

40. Hangebrauck, R. P., and Spaite, P. W. "Pollution from Power Production." Paper presented at the National Limestone Institute Convention, Washington, D. C., January 21-23, 1970.

Predictions of source of fuel for power generation and effect on total emission of SO_2 and NO_X are presented. Methods of controlling air pollution by SO_2 from power plant stack gases are discussed. Cost estimates are included. Emphasis is placed on limestone-based processes and on improved methods of removing particulates. Of the three pollutants, SO_2, N oxides, and particulates, it is indicated that the most immediate and serious problem is posed by SO_2. The most comprehensive program of control technology development at present is aimed at SO_2 control.

41. Hein, L. B., Phillips, A. B., and Young, R. D. "Recovery of SO_2 from Coal Combustion Stack Gases." IN *Problems and Control of Air Pollution* (Frederick S. Mallette, ed.), Reinhold, New York (1955) pp. 155-69.

Pilot plant work was carried out on the absorption step of the process for the recovery of SO_2 from dilute gases using actual combustion gas from high-sulfur coal. The acidification and crystallization steps were studied briefly. Gases from the boiler passed through a dry cyclone dust collector, cooler, humidifier, cyclone collector for entrainment separation, a meter, then a scrubber packed with 2 in. Raschig rings (depth varied 3-8 ft); scrubber liquor was distributed over the packing with a cone distributor. Recirculation rate, pH, concentration of the scrubber liquor, depth of packing, and gas velocity in the scrubber were studied. Optimum pH of liquor was 6.4; packing depth of 3 ft was adequate for high liquor rates, which were around 3 gal/min/sq ft; the whole range of 1.4-3.5 ft/sec gas velocity studied was satisfactory; recovery of SO_2 added was 85%; NH_3 losses were kept low by using ammonium sulfite-bisulfite scrubber in a second stage.

42. Hori, S. (Kitazato University, Tokyo, Japan). Private communication, December 12, 1968.

43. JECCO process. "Ammonium Sulfate Production Without Free Acid." *Economic and Technical Monthly - Japan* 1(1), 22-23 (June 1952).

    Ammonium sulfite solution is reacted with air or O_2 to give ammonium sulfate. Atomized O_2 bubbles are introduced in the solution at 2-3 atm pressure.

44. Johnstone, H. F. "Progress in the Removal of S Compounds from Waste Gases." *Combustion* 5(2), 19-30 (Aug. 1933).

    The possibility of economically washing large quantities of gases with water is very remote. The limits imposed by the solubility of SO_2 from such dilute gases are those of the quantity of water required, and time and surface of contact needed. Bubble type of washing was found to require the least time of contact and smallest volume of washing space.

45. Johnstone, H. F. "Recovery of SO_2 from Waste Gases." *Ind. Eng. Chem.* 27(5), 587-93 (May 1935).

    The partial vapor pressure of the system NH_3-SO_2-H_2O was studied at 35-90° C over a wide range of NH_3 concentrations and SO_2 concentrations in solution. The capacity to absorb 0.3% SO_2 may be as high as 8 lb/100 lb solution.

46. Johnstone, H. F., and Keyes, D. B. "Recovery of SO_2 from Waste Gases." Distillation of a three-component system NH_3-SO_2-H_2O. *Ind. Eng. Chem.* 27(6), 659-65 (June 1935).

    Methods of calculating theoretical plates, or values of diffusional potential, in the regeneration of solutions of NH_4 sulfite-bisulfite saturated with respect to a dilute SO_2 gas are given. Though SO_2 is less volatile than H_2O, its relative concentration in vapor may be increased by the stripping action of vapor countercurrent to the solution if no reflux is returned to the top of the column.

47. Johnstone, H. F., and Singh, A. D. "Recovery of SO_2 from Waste Gases; Design of Scrubbers for Large Quantities of Gases." *Ind. Eng. Chem.* 29(3) 286-97 (Mar. 1937).

    Measurements of the rates of absorption and heat transfer, and of resistance to gas flow were made for different systems. The most desirable packing for large amounts of flue gas is composed of grids with 1½ in. channels and individual sections 4-6 in. high.

48. Johnstone, H. F. "Recovery of SO_2 from Waste Gases." *Ind. Eng. Chem.* 29(12), 1396-98 (Dec. 1937).

    Tests are reported on the effect of solvent concentration on capacity and steam requirements of sulfite-bisulfite solutions. There is an optimum concentration of NH_3 in the solution which produces the maximum capacity and requires a minimum of steam for regeneration; this is a function of the raw gas composition and other operating conditions. For dilute gases at high humidity, the optimum concentration can be one-half the concentration of a saturated solution.

49. Johnstone, H. F., Read, H. J., and Blankmeyer, H. C. "Recovery of SO_2 from Waste Gases. Equilibrium Vapor Pressures Over Sulfite-Bisulfite Solutions." *Ind. Eng. Chem.* 30(1), 101-109 (1938).

    Partial vapor pressures are reported for a wide range of concentrations and compositions of sodium sulfite-bisulfite solutions and of methylamine sulfite-bisulfite solutions at 35, 50, 70, and 90° C. Other solutions, such as ammonium sulfite-bisulfite solutions, were studied to show the effect of the nature of the solution on the temperature coefficient of vapor pressure of SO_2. More steam was required for regeneration of the solution for sodium or methylamin[illegible]n for ammonium solutions.

50. Johnstone, [illegible] F. "Recovery of SO_2 from Waste Gases." *Pulp Paper Mag. Can.* 53(4), 105-12 (Mar. 1952).

    The possibility of recovering SO_2 from waste gases is reviewed as a source of SO_2 for pulp mills. Equilibrium vapor pressure of solutions of NH_3-SO_2-H_2O system indicate that solutions of bisulfite-sulfite can be used efficiently even if SO_2 concentration is 0.4%. Modification of Trail process is suggested. Half of SO_2 that is recovered is converted to ammonium sulfate, the rest used as gas for preparation of cooking liquor.

51. Johnstone, H. F., and West, W. E., Jr. "Recovery of Sulfur Dioxide from Waste Gases." Unpublished report, University of Illinois, Urbana, Illinois, 51 pp.

    The equilibrium vapor pressures over solutions of the NH_3-SO_2-H_2O system indicate that these solutions may be used to recover SO_2 with good efficiency and without serious loss of NH_3, even if the concentration of the original gas is as low as 0.4% SO_2.

52. Karakhanyan, S. S., Grigoryan, G. O., and Makhtesyan, I. M. "Processing of Common Salt. III Decomposition of Apatite Concentrate with Ammonium Bisulfate." *Izv. Akad. Nauk Arm. SSR, Khim. Nauk* 18(5), 516-20 (1965).

Apatite was decomposed by varying the reaction temperature, contact time, and ammonium bisulfate concentration. Optimum conditions were 95°, 2 hr, and 60% ammonium bisulfate; ratio of NH_4HSO_4 to apatite was 164-100 parts by wt.

53. Karakhanyan, S. S., and Grigoryan, G. O. "Processing of Common Salt. IV–Decomposition of Apatite Concentrate with an Ammonium Sulfate Mixture and the Chemistry of the Process." *Izv. Akad. Nauk Arm. SSR, Khim. Nauk* 18(5), 521-28 (1965).

    Apatite was decomposed with a mixture of ammonium sulfate and ammonium bisulfate with a molar ratio of $NH_3:H_2SO_4$ of 1:1.33. Treatment with 50-55% of the sulfate solution, in an amount equivalent to the amount of H_2SO_4 needed for superphosphate manufacture, decomposed 93.4% of the apatite in 1 hr at 90° C. When NH_4HSO_4 was used alone, only 80-83% was decomposed.

54. Karakhanyan, S. S., Grigoryan, G. O., and Mirumyan, R. L. "Processing of Common Salt. V–Preparation of a Nitrogen-Phosphorus Fertilizer by Decomposition of Apatite Concentrate with Ammonium Bisulfate." *Izv. Akad. Nauk Arm. SSR, Khim. Nauk* 18(6), 615-20 (1965).

    Reacting apatite with 50-56% ammonium bisulfate for 2 hr at 95-98° gave 97-99% decomposition of the apatite.

55. Kashtanov, L. I., and Ruizhov, V. P. "The Kinetics of Oxidation of Gaseous SO_2 in Aqueous Solutions, and Poisoning of Manganese Sulfate by Phenol." *Izvestiya Teplotekh. Inst.* No. 7, 37 (1935).

    The oxidation processes occurring in the absorption of SO_2 are similar to those of H_2SO_3 solutions. Ratio of oxidation decreases with increase in stream velocity. Desorption ratio decreases with higher SO_2 concentration in the solution. Mn sulfates increase oxidation velocity by 100%. Presence of phenols in the solution inhibits autoxidation of SO_2; oxidation rate is lowered with higher concentrations of phenol. Action of catalysts is completely inhibited in presence of 0.1% phenol. An insignificant phenol concentration sharply lowers autoxidation velocity in presence and absence of Mn. Phenol concentration of $>0.1\%$ has practically no effect on oxidation processes.

56. Kennaway, T. "The Fulham-Simon-Carves Process for the Recovery of S from Flue Gases." *J. Air Pollution Control Assoc.* 7(4), 266-74 (Feb. 1957).

    A summary is given of the the development of SO_2 pollution control in England. The Battersea effluent process (scrubbing with Thames River water); the Howden ICI cyclic lime process (scrubbing with circulating lime water); and the Simon-Carves process pilot plant at Fulham (scrubbing with NH_4 liquors, then autoclaving to yield ammonium sulfate and sulfur).

57. King, R. A. "Economic Utilization of SO_2 from Metallurgical Gases." *Ind. Eng. Chem.* 42(11), 2241-48 (Nov. 1950).

    The development of a process for the removal of SO_2 from spent gases is described. Important factors were the availability of NH_3 for absorption; of H_2SO_4 for acidification of absorbing solutions to release the SO_2; and the fact that Trail was already producing and marketing ammonium sulfate. Less than 9% of the sulfur charged to the recovery unit was lost to the air.

58. Kyongshin, Yun. "Aqueous Ammonium Sulfate Solutions." Ger. Pat. 1,275,036 (Aug. 14, 1968).

    Aqueous ammonium sulfate solutions are produced by quantitative oxidation of ammonium sulfite solutions with oxygen at 1 atm and 20-70° C using heavy metal oxides and sulfides of group V-VIII metals.

59. Lawler, W. C. "Use of a SO_2 Scrubbing System in Air-Pollution Control." IN *Problems and Control of Air Pollution* (Frederick S. Mallette, ed.), Reinhold, New York (1955), pp. 222-24.

    The Olin-Mathieson development work on the Cominco system of SO_2 recovery with ammonium sulfite-bisulfite solutions is described.

60. Lepsoe, R., and Kirkpatrick, W. S. "SO_2 Recovery at Trail." *Trans. Can. Inst. Mining Met.* XL, 399-404 (1937).

    An outline is given of the SO_2 recovery operations, particularly the absorption and reduction plants; 450 tons/day of sulfuric acid and 45 tons/day of sulfur are produced. A concentrated ammonium bisulfite solution is the product of the absorption system. It is acidified in a packed tower with sulfuric acid, yielding ammonium sulfate and 100% SO_2 gas. The SO_2 is reduced to sulfur in an incandescent coke bed.

61. Lonza Elektrizitaetswerke und Chemische Fabriken A. G. (by A. Egger). "Removal of Sulfur Oxides from Gases Containing CO_2." Swiss Pat. 357,825 (Dec. 15, 1961).

    Stack gases containing SO_2 were scrubbed with NH_4 sulfate-sulfite-bisulfite-carbonate solution at pH 5.5-6.5, yielding ammonium sulfite and bisulfite which were subsequently oxidized to ammonium sulfate. After separation of the product the mother liquor was recycled.

62. Manderson, M. C. "The Sulfur Outlook." *Chem. Eng. Progr.* 64(11), 47-48 (1968).

    The sulfur shortage is no longer a problem, and industry is now moving into a surplus situation. Various sources will meet a demand growth of 4.75%/yr to 1971.

63. Manvelyan, M. G., Grigoryan, G. O., and Karakhanyan, S. S. "Processing of Common Salt. II–Decomposition

of Ammonium Chloride by Sulfuric Acid with Production of Ammonium Bisulfate and Hydrogen Chloride." *Izv. Akad. Nauk Arm. SSR, Khim. Nauk* 18(1), 92-95 (1965).

With a 1:1 mole ratio of NH_4Cl:H_2SO_4, 93.5% H_2SO_4 decomposed the NH_4Cl almost completely in 1 hr at 150° forming HCl and ammonium bisulfate. With 100% H_2SO_4 the decomposition time was ½ hr.

64. Mascarello, J., and Auclair, J. "Sulphur Oxides Removal from Flue Gases in the Large Power Plants of Electricite de France." Paper presented at the American Power Conference, Chicago, Illinois, April 22-24, 1969.

    Most of the plants burn fuel oil. The removal process consists of adding NH_3 to the stack gas when it leaves the air heater, ahead of a primary scrubber. Products are ammonium sulfite, bisulfite, and sulfate. SO_2 is recovered by steam stripping. In a second phase the liquors are treated with a lime slurry to recover NH_3. Precipitated calcium sulfate and sulfite and fly ash are discarded. Investment and operating costs are estimated.

65. Mitchell, D. A. "The Use of Nitric Acid in the Manufacture of Fertilisers." Paper presented at the British Engineering Event in Mexico, February 12-16, 1968.

    Principal methods of producing P fertilizers are reviewed. Nitric phosphate manufacture is described, principally the Odda process in various forms, and the NP/ASU process involving nitric phosphate sulfate recycle. A Dutch State Mines nitric phosphate unit is mentioned which uses byproduct ammonium sulfate from a caprolactam plant, and less contaminated ammonium sulfate from byproduct gypsum.

66. Nakagawa, S. "Removal and Utilization of SO_2 in Stack Gas by the JECCO Process." *Ryusan* 16, 211-18 (1963).

    SO_2 removal by NH_4 sulfite solution or milk of lime is used in this process; ammonium sulfate or gypsum is produced by oxidation with air or oxygen.

67. Nakagawa, S. "Sulfur Dioxide Gas in Exhaust Smoke; Its Removal, Recovery, and Utilization." *Japan Analyst* 15(8), 872-81 (Aug. 1966).

    The need for SO_2 pollution control is discussed. Several methods of absorption and reaction, recovery of products, and regeneration of reactants are described.

68. Nakagawa, S. (Japan Engineering Consulting Company, Tokyo, Japan). Private communication, 1968.

69. Newall, H. E. "Ammonia Process for Removal of SO_2 from Flue Gases." IN *Problems and Control of Air Pollution* (Frederick S. Mallette, ed.), Reinhold, New York (1955), pp. 170-90.

    The Fulham-Simon-Carves process is described; it involves the scrubbing of flue gases with a concentrated solution of ammonium salts and the addition of NH_3 gas to the liquor.

70. Newell, J. E. "Making Sulfur from Flue Gas." *Chem. Eng. Progr.* 65(3), 62-66 (Aug. 1969).

    A description is given of a design study for a plant using the alkalized alumina process to recover sulfur. A typical station with four 500-mw units, burning coal containing 2.3% S is assumed as the source of flue gas. Regenerators are designed to use fluidized bed heaters. An economic evaluation is given.

71. Perry, H., and De Carlo, J. A. "The Search for Low-Sulfur Coal." *Mech. Eng.* 89(4), 22-28 (Apr. 1967).

    Economic aspects of air pollution by SO_2 are discussed. Sources of coal of low S content are reviewed, and the means of removal of S from coal before combustion or from the flue gas afterwards are evaluated.

72. Ramsey. "Use of the NH_3-SO_2-H_2O System as a Cyclic Recovery Method." Brit. Pat. 1,427 (1883). See: "Recovery of SO_2 from Waste Gases." Johnstone, H. F., *Ind. Eng. Chem.* 27(5), 587-93 (May 1935).

73. Rees, R. L. "Removal of SO_2 from Power-Plant Stack Gases." IN *Problems and Control of Air Pollution* (Frederick S. Mallette, ed.), Reinhold, New York (1955), pp. 143-54.

    Flue gas washing processes are described that involve use of water, lime slurries, ammonia solutions, or sodium sulfite-bisulfite slurries combined with zinc oxide slurries for recovery of sulfur.

74. Ross, W. H., Merz, A. R., and Jacob, K. D. "Preparation and Properties of the Ammonium Phosphates." *Ind. Eng. Chem.* 21(3), 286-89 (1929).

    Methods of preparation of three series of salts–meta-, pyro-, and orthophosphates of ammonium–are described and the properties are outlined. Particular attention is given to those compounds which are useful as concentrated fertilizers.

75. Rumanian Minstry of Petroleum Industry and Chemistry. "Ammonium Sulfate." Brit. Pat. 1,097,257 (Jan. 3, 1968).

    At 60-80° C, SO_2 from residual gases was absorbed in presence of O in an ammoniacal soiution containing 5-35% wt NH_3 in the presence of activated charcoal and H_3PO_4. Ammonium sulfate containing 1% ammonium sulfite is recovered.

76. Scott, W. D., and McCarthy, J. L. "The System SO_2-NH_3-H_2O at 25° C." *Ind. Eng. Chem., Fundamentals* 6(1), 40-48 (Feb. 1967).

    Experiments were conducted using modified standard procedures to obtain IR absorption spectra, pH values, and electrical conductivity data for

solutions over the entire range of mole ratio $NH_3:SO_2$. It was determined that H_2SO_3, NH_4OH, and $S_2O_5^{=}$ do not exist in the solution system to any appreciable extent, and that, at pH values of > 4.2 and < 9.5 H^+ and OH^- exist in only negligible amounts.

77. Sanderhaut, Frantisek (Fuel Research Institute, Prague, Czechoslovakia). Private communication, May 1969.

78. Tans, A. M. P. "A New Type of Nomogram–Aqueous Ammonium Sulfate Solutions." *Ind. Eng. Chem.* 50(6), 971-72 (June 1958).

    The density, vapor pressure, and viscosity of solutions of varying concentration at different temperatures are included in one nomograph.

79. Tarbutton, G., Driskell, J. C., Jones, T. M., Gray, F. J., and Smith, C. M. "Recovery of Sulfur Dioxide from Flue Gases." *Ind. Eng. Chem.* 49, 392-95 (Mar. 1957).

    A simple, direct acid process for recovery of SO_2 was studied. A small amount of ozone was added to flue gas and the mixture was scrubbed in a packed tower with H_2SO_4 solution containing Mn. Maximum concentration of H_2SO_4 obtained was about 40%. SO_2 recovery was higher when more dilute acid was used as a scrub liquor.

80. Tennessee Valley Authority. Progress Report Assembly No. 47A (Feb. 1954-Sept. 1955) (unpublished). "Recovery of Sulfur Dioxide from Flue Gases."

    Miscellaneous small-scale, bench-scale, and pilot plant tests on the recovery or removal of SO_2 from flue gases are described. The effects of use of HNO_3, $MnSO_4$, solid MnO ore, or nascent O in the scrubbing system, or a supported Pt or Cu catalyst in the hot gas stream were investigated. A scrubbing tower containing lumps of MnO ore was tested with promising results.

81. Tennessee Valley Authority. Applied Research Branch monthly progress reports (Oct.-Nov. 1967; Jan. 1968) (unpublished).

    Small-scale tests of reactions of phosphate rock with hot ammonium bisulfite solutions are described. Use of SO_2 to produce sulfuric acid for fertilizer production was also investigated.

82. Tennessee Valley Authority. "Sulfur Oxide Removal from Power Plant Stack Gas: Sorption by Limestone or Lime–Dry Process" (1968). Report No. PB 178-972, Clearinghouse for Scientific and Technical Information, 5285 Port Royal Road, Springfield, Virginia 22151.

    Injection of dry limestone or lime into the boiler is considered the simplest and least costly process for removing SO_2 from power plant stack gases. Product is calcium sulfate which is discarded. The process can be operated intermittently. A detailed economic evaluation is presented.

83. Tennessee Valley Authority. "Sulfur Oxide Removal from Power Plant Stack Gas: Use of Limestone in Wet-Scrubbing Process" (1969). Report No. PB 183-908, Clearinghouse for Scientific and Technical Information, 5285 Port Royal Road, Springfield, Virginia 22151.

    Use of limestone or lime in a wet scrubber is one of the more promising methods of recovery of SO_2, and has the advantage of simultaneous removal of fly ash. The lime can be injected into the boiler and caught in a wet scrubber after the air heater; this method removes some SO_2 ahead of the scrubber, provides some protection from corrosion, and converts the lime into a more reactive form. Another method is to introduce the lime into the scrubber system; this eliminates many boiler and equipment operating problems. Plume cooling and water pollution problems are discussed. Economics are reported.

84. Tennessee Valley Authority. "Economic Factors in Recovery of Sulfur Dioxide from Power Plant Stack Gas." Paper presented at the 62d annual meeting of Air Pollution Control Association, New York, New York, June 22-26, 1969.

    Methods for determining the capital and operating costs for SO_2 removal processes are presented. Both throwaway- and recovery-type processes are considered. The importance of load factor, return on investment and marketing is discussed.

85. Toyo Koatsu Industries, Inc. (by M. Okuide, T. Tanaka, and O. Shigeno). Jap. Pat. 19,824 (Oct. 19, 1961).

    Ammonium sulfate solutions containing ammonium sulfite and $(NH_4)_2S_4O_6$ were electrolyzed. Most unstable S compounds were oxidized. A noncorrosive ammonium sulfate solution was obtained.

86. United States Department of Agriculture. "Consumption of Commercial Fertilizers in the United States." Year ended June 30, 1967, 11 pp.

    Totals of consumption of fertilizer, of N, of P, of K, and of primary plant nutrients are each tabulated by states. Some distinction of sources is made.

87. United States Department of the Interior. Bureau of Mines Report of Investigations No. 3339. "Fixation of Sulfur from Smelter Smoke." (May 1937), 51 pp.

    The present status of sulfur fixation and plans of investigations are discussed. In the Guggenheim process, ammonium sulfite solution absorbs SO_2 yielding ammonium bisulfite which, on heating, gives off SO_2 with regeneration of the sulfite. Vapor pressures and thermodynamic properties of ammonium sulfites were determined. Four crystalline compounds are discussed: $(NH_4)_2SO_3$, $(NH_4)_2SO_3 \cdot H_2O$, NH_4HSO_3, and $(NH_4)_2S_2O_5$. The last-named is the only one that was found to decompose directly into its gaseous components; this was the only one whose vapor pressure could be measured. The recovery of sulfur in solid compounds (sulfites) by the addition of NH_3 and water vapor to smelter gas is described. Such a process should be cyclic to permit reuse of NH_3. It was found that if sufficient moisture is present and an efficient system of baffles is used, practically complete precipitation takes place. If the temperature is below 50° C, losses of ammonium sulfite will be fairly large. The oxidation of ammonium sulfite solution is discussed.

88. United States Department of Interior. Bureau of Mines Report of Investigations No. 5469. "Cost Estimates of Liquid Scrubbing Processes for Removing Sulfur Dioxide from Flue Gases." (1959), 51 pp.

    Estimated capital and operating costs are reported for removing SO_2 from flue gases of a power plant of 120-mw capacity by liquid purification processes, using limestone, ammonia, or sodium sulfite as the reactant.

89. Vasilenko, N. A. "The System Ammonium Sulfate-Ammonium Sulfite-Ammonium Bisulfite-Water; a 30° Isotherm." *J. Appl. Chem. USSR* 26(6), 601-603 (1953).

    These phases were found in equilibrium with the solutions at the junction points of the diagram at 30° C:

    Liquid phase: $(NH_4)_2SO_3$ 25.74, $(NH_4)_2SO_4$ 24.33 wt %; no NH_4HSO_3;
    Solid phase: $(NH_4)_2SO_4 + (NH_4)_2SO_3 \cdot H_2O$
    Liquid phase: $(NH_4)_2SO_4$ 6.52, NH_4HSO_3 73.83 wt %; no $(NH_4)_2SO_3$;
    Solid phase: $(NH_4)_2SO_4 + (NH_4)_2S_2O_5$
    Liquid phase: $(NH_4)_2SO_3$ 12.75, NH_4HSO_3 66.73 wt %; no $(NH_4)_2SO_4$;
    Solid phase: $(NH_4)_2SO_3 \cdot H_2O + (NH_4)_2S_2O_5$

90. Vian-Ortuno, A., and Martin-Municio, V. (to Empresa Auxiliar de la Industria, S. A.). "Method for Oxidizing Ammonium Sulfite to Ammonium Sulfate." U. S. Pat. 3,330,620 (July 11, 1967).

    An organic, N-containing base, such as pyridine, is dispersed in a solution of ammonium sulfite to completely oxidize the sulfite to sulfate at 80-90° C. The amount used is 10-80% of the volume of the dispersion.

91. Volgin, B. P., Efimova, T. F., and Gofman, M. S. "Absorption of SO_2 by Ammonium Sulfite-Ammonium Bisulfite Solutions in a Venturi Scrubber." *Int. Chem. Eng.* 8(1), 113-18 (Jan. 1968).

    A venturi scrubber was said to be 6 times as effective as a bubble-type absorber, and 60 times as effective as a packed absorber, although the resistance is also higher by 38%. The venturi data are based on small-scale apparatus and are compared with larger scale data.

92. Vorlander, D., and Lainau, A. "The Oxidation of Ammonium Sulfite to Ammonium Sulfate by Means of Air, in the Presence of Mineral Salts." *J. Prakt. Chem.* 123(2), 351-76 (1930).

    A literature survey with 20 references on oxidation of ammonium sulfite to ammonium sulfate is given. Tests were made using air and/or mineral salts. $CoSO_4$ was the best catalyst, optimum pH 8.4, and the effect was detectable at very low concentrations.

93. Wallis, E. "Atmospheric Pollution and the Zinc Industry." *Chem. Ind. (London)* No. 41, 1271-73 (Oct. 8, 1955).

    Exit gases from a contact sulfuric acid plant were treated to remove SO_2. In the first step, 32,500 cu ft/min exit gas was scrubbed with an ammonium sulfite-ammonium bisulfite solution; then the liquor was acidified to give ammonium sulfate and SO_2. The ammonium sulfate was stripped of SO_2 with air and passed to a crystallizer.

94. West, W. E., Jr., Thesis "Evaluation of Sulfur Dioxide Recovery Processes." University of Illinois, Urbana, Illinois (1953), 99 pp.

    Economic comparisons of eight processes are given: Trail (hot gases); Trail (cool gases); steam stripping + acidification; acidification + steam stripping; acidification + steam stripping–$SO_4^{=}$ removal by cooling and crystallization; low SO_2 recovery, low $SO_4^{=}$ production; autoclave; and air oxidation of the rich effluent.

95. Wood, C. W. (Simon Engineering, Ltd., Stockport, England). Private communication, January 7, 1969.

96. Yamamoto, M. (Mitsubishi Shoji Kaisha, Ltd., Tokyo, Japan). Private communication, March 19, 1969.

APPENDIX A
OPTIMUM PRICING STRATEGY

Fertilizer products generally have low values/unit wt. As a result, the spatial aspects of marketing are important. In deciding how to market a product, the firm must consider the alternatives of intensive vs extensive marketing. Under intensive marketing, the tendency is to sell large quantities of product close to the point of production. This results in low transportation costs, but also low product prices. Under extensive marketing, the tendency is to "skim the cream" from the market at any given point and ship the product as far as necessary to dispose of it. This results in higher transportation costs, but higher product prices. In choosing its optimum strategy, the firm substitutes extensive marketing practices for intensive ones until the marginal value added to net revenue from each is equated.

A number of pricing strategies are found in the fertilizer industry. Four alternative strategies for pricing, the byproducts in question are considered in this appendix: (1) delivered price competitive with ammonium nitrate, (2) delivered price competitive with diammonium phosphate, (3) dual zone pricing (combination of 1 and 2), and (4) fob pricing. The desirability of each strategy is quantified in terms of the amount of revenue that is generated by the sale of a given quantity of product. A single production location is considered and the potential market is composed of all points in the area surrounding the production point. It is assumed that all market points are similar in the quantities and types of fertilizer consumed. It is also assumed that the prices of competing products are the same at all market points. As a result of the above assumptions, the demand curve (maximum price a blender can pay for a given quantity of product) at each market point is the same for all points. From the prices in table 23 (see main text) and the assumed densities 0.25 and 1.00 ton of N/sq mi, the demand curve for each byproduct can be derived. The demand curve for 28-14-0 is shown in figure A-1. At prices greater than \$52.47/ton, consumption density is zero. At prices greater than \$43.49/ton but less than \$52.47/ton, consumption density is 0.25 ton of 28-14-0 N/sq mi or 0.893 ton of product/sq mi. In this price range blenders substitute 28-14-0 N for ammonium nitrate or other straight N. At prices less than \$43.49/ton blenders use only 28-14-0 N for a density of 1.00 ton of N/sq mi or 3.57 tons of 28-14-0/sq mi. At lower prices, higher densities can be expected but this portion of the demand curve was not included in the present study.

In choosing a pricing strategy the firm must face the realities expressed in the demand curve for its product. While the firm would like a very high price, such a strategy would result in no sales or zero revenue. At a price of \$52.47 (P_1), figure A-1 shows that the revenue from the point in question will be \$46.85/sq mi [$P_1D_1 = (52.47)(0.25)/(0.28) = 46.85$]. ($D_1$ is the ratio of consumption density to N content of the product.) At a slightly lower price there is no increase in density so revenue decreases. Obviously the firm wants the maximum price for a given density. But suppose price is lowered to \$43.49 (P_2); the revenue then is

$$P_2D_2 = (43.49)(1.00)/(0.28) = \$155.32/\text{sq mi},$$

which is an increase of

$$P_2D_2 - P_1D_1 = 155.32 - 46.85 = \$108.47/\text{sq mi}.$$

Marginal revenue (P_k^*) at a given market point is the change in total revenue/unit change in density,

$$P_k^* = \frac{\Delta TR_k}{\Delta D_k} = \frac{P_kD_k - P_{k-1}D_{k-1}}{D_k - D_{k-1}}.$$

For example,

$$P_1^* = 52.47 \text{ (since } D_O = O)$$

and,

$$P_2^* = \frac{43.49(1.00) - 52.47(.25)}{1.00 - .25} = 40.50,$$

which uses nitrogen consumption densities, since the nitrogen content (.28) cancels out. Marginal revenue from adding a new market point–going from D_O=0 to D_1=.89–is \$52.47/ton, while marginal revenue from selling more product at a given point–going from D_1=.89 to D_2=3.57–is only \$40.50/ton. Hence, if a new market point can be added without increasing distribution cost it would pay to do so.

Distribution cost to a point r miles from the production point is defined as,

$$TDC_k(r) = m(P_kD_k) + (h_o + hr)D_k,$$

where,

m = sales cost, %
h_o = handling cost, \$/ton
h = transportation cost, \$/ton-mile.

Total returns to manufacturing from a given market point is total revenue at that point (P_kD_k) minus total distribution cost,

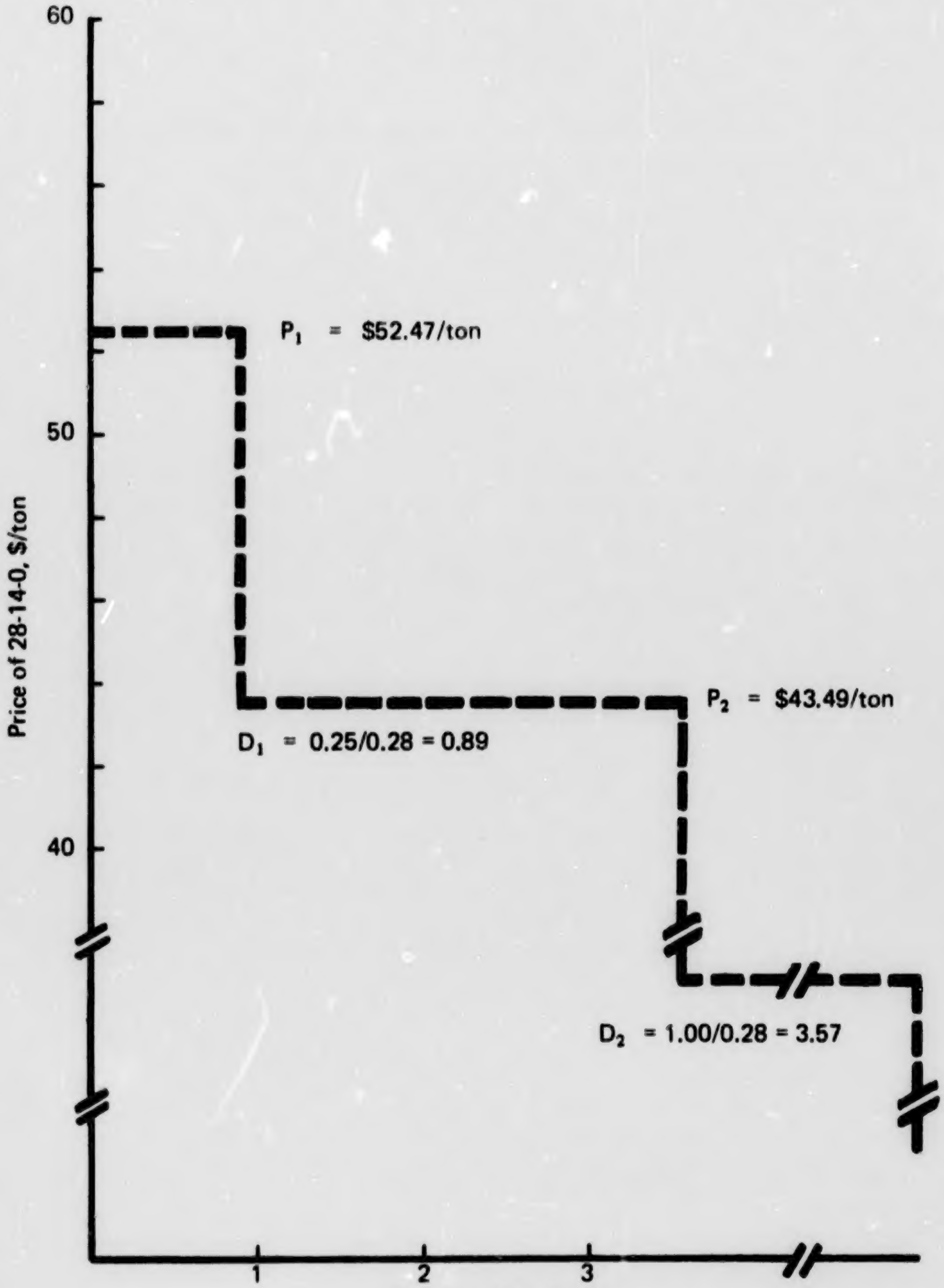


Figure A-1. Demand for 28-14-0 at a Given Market Point

$$TRM_k(r) = [(1\text{-}m)P_k - h_o - hr]\,D_k.$$

Marginal returns to manufacturing at a given point is,

$$MRM_k(r) = \frac{\triangle TRM_k}{\triangle D_k} = \frac{TRM_k - TRM_{k-1}}{D_k - D_{k-1}}$$

$$= (1\text{-}m)\,P_k^* - h_o - hr,$$

which is analogous to and contains marginal revenue, P_k^*.

It was shown above that if distribution costs are ignored, then it pays to supply the lower density D_1 and receive the higher price P_1. However, when market radius reaches R_1^c, which just equates the marginal returns to manufacturing MRM_2 (o) and MRM_1 (R_1^c), then it pays to supply points near the plant at the higher density D_2. This critical radius can be seen to be,

$$R_1^c = (1\text{-}m)\,(P_1^* - P_2^*)/h.$$

Once this critical radius is exceeded, the firm supplies additional product in such a manner as to maintain the equality,

$$MRM_1(R_1) = MRM_2\ (R_2),$$

where R_1 and R_2 are the radii of the markets in which the densities D_1 and D_2 are supplied. Given the above linear distribution cost model, the optimum relationship between these two radii can be shown to be the constant,

$$R_2 = R_1 - R_1^c \geqslant 0,$$

where R_2 cannot be negative. The above pricing strategy is called dual zone delivered pricing, though for small quantities of product there may actually be only one zone, and for large quantities a third zone might pay.

Dual zone delivered pricing maximizes the firm's total return to manufacturing a given quantity of product and hence is the firm's optimum pricing strategy. To see this it is first necessary to construct the firm's total returns to manufacturing function, which is the sum of returns over all market points. In general, the firm's market consists of concentric circles with radii,

$$R = R_1 > R_2 > \ldots > R_S > R_{S+1} = 0,$$

in which the appropriate densities are,

$$D_S > D_{S-1} > \ldots > D_2 > D_1 > D_o = 0.$$

Total returns to manufacturing is found by polar coordinate integration to be,

$$TRM = \sum_{k=1}^{S} \int_{0}^{2\pi} \int_{R_{k+1}}^{R_k} TRM_k(r)\, rdr\, d\theta$$

$$= \sum_{k=1}^{S} \int_{0}^{2\pi} \int_{0}^{R_k} MRM_k(r) \triangle D_k\, rdr\, d\theta,$$

where the angle θ is the direction of any market point from the plant. The quantity of product is calculated in an analogous manner as,

$$X = \sum_{k=1}^{S} \int_{0}^{2\pi} \int_{R_{k+1}}^{R_k} D_k\, rdr\, d\theta$$

$$= \sum_{k=1}^{S} \int_{0}^{2\pi} \int_{0}^{R_k} \triangle D_k\, rdr\, d\theta.$$

When evaluating the above integrals between 0 and R_k, it is convenient to define added quantities of product as,

$$X_k = \int_{0}^{2\pi} \int_{0}^{R_k} \triangle D_k\, rdr\, d\theta$$

so that,

$$X = \sum_{k=1}^{S} X_k.$$

It is also convenient to define market proportions as

$$x_k = X_k/X,$$

so that,

$$\sum_{k=1}^{S} x_k = 1.$$

When the above integrals are evaluated, it is found that,

$$TRM = \sum_{k=1}^{S} [\,(1\text{-}m)\,P_k^* - h_o - h\ 2/3R_k]\,X_k$$

and,

$$X = \sum_{k=1}^{S} \triangle D_k \, \pi R_k^2.$$

Note that the added quantity of product in the k^th^ market (x_k) is equal to the added density ΔD_k times the area of the k^th^ circle. Average returns to manufacturing is,

$$\begin{aligned} ARM &= TRM/X \\ &= \sum_{k=1}^{S} ARM_k \, x_k, \end{aligned}$$

where average returns in the k^th^ market is,

$$ARM_k = (1\text{-}m)\, P_k^* - h_o - h\, ALH_k.$$

Average length of haul in the k^th^ market is,

$$ALH_k = 2/3 R_k,$$

which is two-thirds of the market radius.

The total returns to manufacturing maximizing problem can now be stated as: find positive values of R_k which maximize TRM, given a quantity of product X. This problem is equivalent to maximizing the Lagrangian expression,

$$TRM = \sum_{k=1}^{S} \int_0^{2\pi} \int_0^{R_k} (MRM_k - L) \triangle D_k \, r dr \, d\theta + LX,$$

where the Lagrangian multiplier is L. By partial differentiation under the integral, the first order maximizing condition can be shown to be,

$$\begin{aligned} MRM_k (R_k) &= L \quad (k=1,2,\ldots,S), \\ R_k &\geqslant 0. \end{aligned}$$

This is just the optimizing condition stated earlier, which is to supply all markets in such a manner as to equate all marginal returns to manufacturing. If this rule implies that some R_k are negative, then these levels of density are not supplied.

An alternative strategy is to maintain a uniform delivered price. Actually this is the optimum strategy for supplying relatively small quantities of product. Hence, by setting (S=1) in the above results it is seen that,

$$ARM = (1\text{-}m)\, P_1 - h_o - h\, ALH_1$$

and

$$X = D_1 \pi R_1^2,$$

since,

$$P_1^* = P_1$$

and

$$D_o = 0$$

As a result,

$$\begin{aligned} ALH_1 &= 2/3(X/\pi D_1)^{1/2} \\ &= 0.3761264(x/D_1)^{1/2}, \end{aligned}$$

so that average length of haul increases in proportion to the sq root of the quantity of product. Another pricing strategy considered for comparative purposes is delivered pricing competitive with diammonium phosphate. Average returns to manufacturing are calculated under this strategy by using the above formulas and (P_2,D_2).

Another pricing strategy, found in phosphate fertilizer marketing, is to establish an fob price and let the buyer pay the freight. This is probably the simplest strategy and involves the smallest investment in a marketing organization. Buyers arrange for their own transportation, and the producer is relieved of the task of maintaining delivered prices. The producer maximizes returns to manufacturing by setting the price P_f at its maximum level consistent with disposal of a given quantity of product. This price is determined so as to obtain zero consumption density on the boundary of the market, R_1 miles out. This means that the delivered product price at this distance must just equal P_1.

$$P_1 = P_f + h_o + hR_1.$$

At this distance density is D_1, but at any greater distance density is zero. If a small quantity of product is to be sold, P_f may exceed P_2 so that the quantity D_1 is purchased at every point. However, as larger quantities are considered, P_f is forced below P_2. Such lower fob prices have a partially compensating advantage in that density near the plant increases to D_2. The distance at which this increased density occurs, R_2, is that at which delivered price just equals P_2,

$$P_2 = P_f + h_o + hR_2.$$

At any greater distance the blender's price is above P_2 and he would purchase only the quantity D_1. The relationship between these two market radii is thus,

$$P_1 - hR_1 = P_2 - hR_2$$

or

$$R_1 - R_2 = (P_1 - P_2)/h$$

so that the difference between the two radii is constant. Under the fob pricing strategy buyers near the plant pay the lowest delivered prices and buyers on the edge of the market pay the highest prices, but since the highest price cannot exceed P_1, all but the most distant buyers pay lower delivered prices.

Under this fob pricing strategy, average return to manufacturing is

$$\begin{aligned} ARM_f &= (1-m)\,P_f \\ P_f &= P_1 - h_o - hR_1 \end{aligned}$$

and the quantity of product is calculated as

$$X = D_1 \pi R_1^2 + \Delta D_2 \pi R_2^2,$$

where

$$R_2 = R_1 - (P_1 - P_2)/h \geqslant 0.$$

The procedure for calculating average returns is to vary R_1 and find the resulting values of ARM and X.

Average returns to manufacturing under the four pricing strategies discussed above are shown in figure A-2 for different levels of N supplied as 28-14-0. Sales cost is assumed to be 12% of price and transportation is assumed to be by rail. The average length of haul in rail miles, ALH_1^*, has been found to closely approximate the relationship,

$$ALH^* = 20 + 1.13ALH,$$

for a wide range of U. S. locations. Average transportation cost for 50-ton rail shipments has been found to closely approximate the relationship,

$$ATC = 0.883 + 0.01558ALH^*,$$

for distances less than 350 miles. By substituting the first of these linear approximations into the second, it is seen that

$$\begin{aligned} h_o &= 1.195 \\ h &= 0.0176. \end{aligned}$$

Consider first the alternative of fob pricing vs delivered pricing at the high price P_1. The average returns from these alternatives are,

$$\begin{aligned} ARM_f &= 0.88[52.47 - 1.20 - 0.0176R_1] \\ ARM_f &= 0.88(52.47) - 1.20 - 0.0176(2/3)R_1\,. \end{aligned}$$

Sales cost under fob pricing is less, but transportation cost is more in the sense that it is evaluated at the market radius instead of the average length of haul. Under delivered pricing, the firm averages out transportation cost by charging nearby consumers higher prices. The fob pricing strategy yields the greater average return as long as small quantities of product are sold. Calculations based on the above equations show that when market radius is less than 38 miles, fob pricing is the optimum strategy. Figure A-2 shows that fob pricing may again be better when very large quantities of product are sold. For intermediate quantities, however, losses up to about $1.90/ton result from fob instead of delivered pricing.

It may be a natural tendency for a power company to choose the simplest possible marketing strategy. With fob pricing the firm need not be concerned with such things as transportation, field storage, and service representatives. The company just announces a price and those who want the product buy it. The cost of this simplicity can be significant, howevever, as seen in figure A-2.

The average returns which result if the firm markets its product intensively are shown by the lower curve in figure A-2. For the size plants to be considered, returns are $5-6/ton lower if the higher density rather than the low density is obtained. If very large quantities of product are sold at a single delivered price, however, it eventually pays to set the low rather than the high price. Of course, at such volumes significant revenue is lost if dual zone pricing is not attempted.

The optimum pricing strategy is clearly seen in figure A-2 to be dual-zone delivered pricing, though for quantities of N less than about 280,000 tons/yr (about one million tons of 28-14-0 product), it pays to maintain only one zone. Even for twice this much product, there is little incentive to maintain a dumping zone near the plant. For very large quantities of product, however, the benefits of dual-zone pricing are significant. Dual-zone pricing is optimum if it can be executed, but this pricing strategy is not stable in the long-run. A tendency exists for product to be purchased in the low-price zone and resold in the high-price zone. Such arbitrage is limited only by the added costs of reselling the product. In some cases reselling costs may be sufficient to make arbitrage unprofitable, but in other cases a third zone develops between the two main zones in which price differences tend to be smoothed out. The shaded area in figure A-2 represents the expected range of average returns to manufacturing a given quantity of N in 28-14-0. It is likely that the firm can obtain returns near the upper end of this range for the byproducts in question.

Formulas for calculating the optimum average returns to manufacturing for each of the byproducts in question are summarized in table A-1. These average returns are for a single delivered price pricing strategy and are valid for values less than the indicated critical values. For greater values a dual-zone price strategy tends to be best. Critical values are expressed as market radius, quantity of N, quantity of product, and power plant size assuming 3.5% sulfur coal. In the present study these critical values are not exceeded, so that delivered pricing competitive with ammonium nitrate is the best strategy.

Table A-1. Optimum Average Return to Manufacturing For Alternative Byproducts, Where Values Less Than The Indicated Critical Values Prevail

	Grade			
	28-14-0	26-19-0	20-15-0	21-0-0
Delivered Price, $/ton				
P_1	52.47	55.09	42.79	28.21
P_2	43.49	47.69	37.15	19.83
Marginal Revenue, $/ton[a]				
P_1^*	52.47	55.09	42.79	28.21
P_2^*	40.50	45.22	35.27	17.04
Critical Radius, mi[b]	598.5	493.5	376.0	558.5
Critical Quantity of Nitrogen, ton/yr	281,332	191,278	111,037	244,983
Critical Quantity of Product, ton/yr	1,004,757	735,685	555,185	1,166,586
Critical Plant Size, mw[c]	1,270	1,280	1,740	2,860
$ARM = a - b x^{1/2}$				
a	44.98	47.28	36.46	23.63
b	.007006	.006751	.005921	.006067
$ALH = cx^{1/2}$				
c	.3980	.3836	.3364	.3447

[a] $P_1^* = P_1 ; P_2^* = [(1.00P_2 - (0.25)P_1)]/0.75.$

[b] $R_1^c = (P_1^* - P_2^*)\ (0.88)/0.0176.$

[c] Assuming 7,000 hr/yr and 3.5% S in coal.

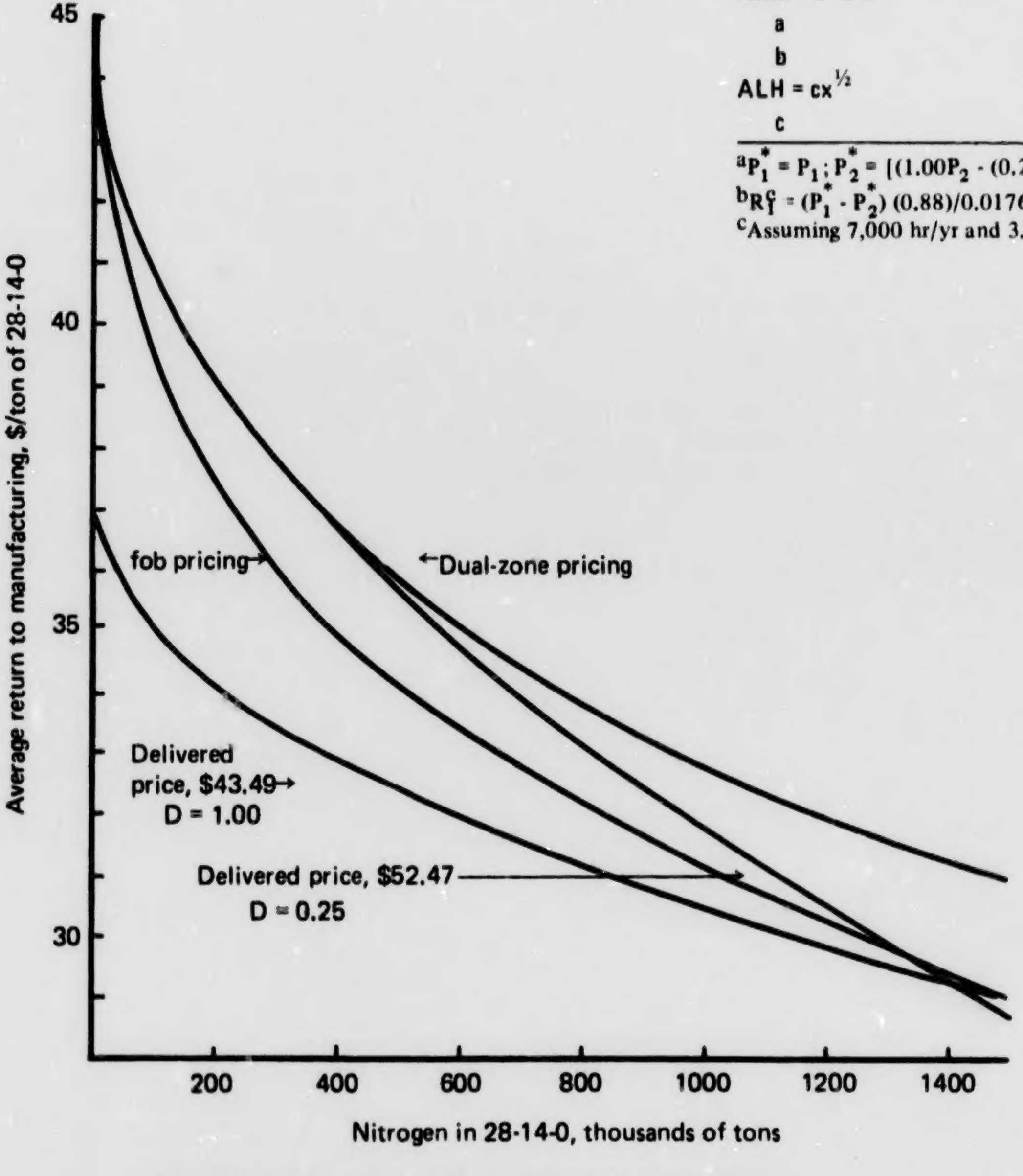


Figure A-2. Comparison of Alternative Pricing Strategies

APPENDIX B
COST ESTIMATES

Table B-1. Summary of Estimated Fixed Investment:[a]
Process A–Ammonia Scrubbing, 28-14-0 Fertilizer Manufacture
(200-mw existing power unit, 3.5% S in coal; 17.4 tons/hr fertilizer)

	Investment, $
Ammonia Scrubbing	
Utilities and storage (ammonia storage and utilities distribution systems)	131,000
Scrubbers and fans (two 3-stage scrubbers with mist eliminators, exhaust fans to stack, and pumps)	925,000
Stack gas reheat system (4 gas-liquid heat exchangers and circulating pumps)	670,000
Oxidizer system(sulfiter, solution storage, oxidizer, and pumps)	407,000
Subtotal direct investment	2,133,000
Engineering design	213,000
Contractor fees and overhead	321,000
Contingency allowance	213,000
Subtotal fixed investment	2,880,000
28-14-0 Fertilizer Manufacture	
Yard, utilities, and storage facilities (raw materials storage, railroad unloading and shipping, utilities distribution)	1,184,000
Nitric acid plant (60% nitric acid)	1,900,000
Extraction-filtration (equipment for acidification of phosphate rock, ammonium sulfate addition, and gypsum filtration)	900,000
Neutralization-prilling (equipment for neutralization, evaporation prilling, screening, and conveying product)	2,210,000
Bulk storage (storage and shipping buildings, 90 days' storage)	790,000
Waste disposal (gypsum and residual ash disposal system including settling pond and land)	206,000
Subtotal direct investment	7,190,000
Engineering design	719,000
Contractor fees and overhead	1,012,000
Contingency allowance	719,000
Subtotal fixed investment	9,640,000
Total fixed investment for project	12,520,000

[a] Basis:
Stack gas reheat to 250°F, by indirect gas-liquid method.
Direct solids disposal as 10% slurry (no return of water but overflow neutralized).
Disposal pond distance of 1 mile.
Midwest plant location–1969 costs.

Table B-2. Summary of Estimated Fixed Investment:[a] Process A—Ammonia Scrubbing, 28-14-0 Fertilizer Manufacture

(500-mw new power unit, 2.0% S in coal;
24.8 tons/hr fertilizer)

	Investment, $
Ammonia Scrubbing	
Utilities and storage (ammonia storage and utilities distribution systems)	141,000
Scrubbers and fans (four 4-stage scrubbers with mist eliminators, exhaust fans to stack, and pumps)	2,060,000
Stack gas reheat system (8 gas-liquid heat exchangers and circulating pumps)	1,500,000
Oxidizer system (sulfiter, solution storage, oxidizer, and pumps)	518,000
Subtotal direct investment	4,219,000
Engineering design	337,000
Contractor fees and overhead	507,000
Contingency allowance	422,000
Subtotal fixed investment	5,485,000
28-14-0 Fertilizer Manufacture	
Yard, utilities, and storage facilities (raw materials storage, railroad unloading and shipping, utilities distribution)	1,267,000
Nitric acid plant (60% nitric acid)	2,420,000
Extraction-filtration (equipment for acidification of phosphate rock, ammonium sulfate addition, and gypsum filtration)	980,000
Neutralization-prilling (equipment for neutralization, evaporation prilling, screening, and conveying product)	2,720,000
Bulk storage (storage and shipping buildings, 90 days' storage)	1,010,000
Waste disposal (gypsum and residual ash disposal system including settling pond and land)	225,000
Subtotal direct investment	8,622,000
Engineering design	690,000
Contractor fees and overhead	1,036,000
Contingency alowance	862,000
Subtotal fixed investment	11,210,000
Total fixed investment for project	16,695,000
Investment savings for 99% effective electrostatic precipitator	(905,000)
Net fixed investment for project assuming precipitator savings	15,790,000

[a] Basis:
Stack gas reheat to 250°F. by indirect gas-liquid method.
Direct solids disposal as 10% slurry (no return of water but overflow neutralized).
Disposal pond distance of 1 mile.
Midwest plant location—1969 costs.

Table B-3. Summary of Estimated Fixed Investment:[a] Process A—Ammonia Scrubbing, 28-14-0 Fertilizer Manufacture

(500-mw new power unit, 3.5% S in coal; 43.4 tons/hr fertilizer)

	Investment, $
Ammonia Scrubbing	
Utilities and storage (ammonia storage and utilities distribution systems)	205,000
Scrubbers and fans (four 4-stage scrubbers with mist eliminators, exhaust fans to stack, and pumps)	2,060,000
Stack gas reheat system (8 gas-liquid heat exchangers and circulating pumps)	1,500,000
Oxidizer system (sulfiter, solution storage, oxidizer, and pumps)	768,000
Subtotal direct investment	4,533,000
Engineering design	363,000
Contractor fees and overhead	541,000
Contingency allowance	453,000
Subtotal fixed investment	5,890,000
28-14-0 Fertilizer Manufacture	
Yard, utilities, and storage facilities (raw materials storage, railroad unloading and shipping, utilities distribution)	1,843,000
Nitric acid plant (60% nitric acid)	3,200,000
Extraction-filtration (equipment for acidification of phosphate rock, ammonium sulfate addition, and gypsum filtration)	1,100,000
Neutralization-prilling (equipment for neutralization, evaporation prilling, screening, and conveying product)	3,830,000
Bulk storage (storage and shipping buildings, 90 days' storage)	1,770,000
Waste disposal (gypsum and residual ash disposal system including settling pond and land)	243,000
Subtotal direct investment	11,986,000
Engineering design	958,000
Contractor fees and overhead	1,437,000
Contingency allowance	1,199,000
Subtotal fixed investment	15,580,000
Total fixed investment for project	21,470,000
Investment savings for 99% effective electrostatic precipitator	(905,000)
Net fixed investment for project assuming precipitator savings	20,565,000

[a] Basis:
Stack gas reheat to 250° F. by indirect gas-liquid method.
Direct solids disposal as 10% slurry (no return of water but overflow neutralized).
Disposal pond distance of 1 mile.
Midwest plant location—1969 costs.

Table B-4. Summary of Estimated Fixed Investment:[a]
Process A—Ammonia Scrubbing, 28-14-0 Fertilizer Manufacture

(500-mw existing power unit, 3.5% S in coal;
43.4 tons/hr fertilizer)

	Investment, $
Ammonia Scrubbing	
Utilities and storage (ammonia storage and utilities distribution systems)	228,000
Scrubbers and fans (four 3-stage scrubbers with mist eliminators, exhaust fans to stack, and pumps)	2,150,000
Stack gas reheat system (8 gas-liquid heat exchangers and circulating pumps)	1,500,000
Oxidizer system (sulfiter, solution storage, oxidizer, and pumps)	768,000
Subtotal direct investment	4,646,000
Engineering design	465,000
Contractor fees and overhead	654,000
Contingency allowance	465,000
Subtotal fixed investment	6,230,000
28-14-0 Fertilizer Manufacture	
Yard, utilities, and storage facilities (raw materials storage, railroad unloading and shipping, utilities distribution)	2,047,000
Nitric acid plant (60% nitric acid)	3,200,000
Extraction-filtration (equipment for acidification of phosphate rock, ammonium sulfate addition, and gypsum filtration)	1,100,000
Neutralization-prilling (equipment for neutralization, evaporation prilling, screening, and conveying product)	3,830,000
Bulk storage (storage and shipping buildings, 90 days' storage)	1,770,000
Waste disposal (gypsum and residual ash disposal system including settling pond and land)	243,000
Subtotal direct investment	12,190,000
Engineering design	1,097,000
Contractor fees and overhead	1,584,000
Contingency allowance	1,219,000
Subtotal fixed investment	16,090,000
Total fixed investment for project	22,320,000

[a] Basis:
Stack gas reheat to 250° F. by indirect gas-liquid method.
Direct solids disposal as 10% slurry (no return of water but overflow neutralized).
Disposal pond distance of 1 mile.
Midwest plant location—1969 costs.

Table B-5. Summary of Estimated Fixed Investment:[a] Process A—Ammonia Scrubbing, 28-14-0 Fertilizer Manufacture

(500-mw new power unit, 5.0% S in coal; 62.0 tons/hr fertilizer)

	Investment, $
Ammonia Scrubbing	
Utilities and storage (ammonia storage and utilities distribution systems)	262,000
Scrubbers and fans (four 4-stage scrubbers with mist eliminators, exhaust fans to stack, and pumps)	2,060,000
Stack gas reheat system (8 gas-liquid heat exchangers and circulating pumps)	1,500,000
Oxidizer system (sulfiter, solution storage, oxidizer, and pumps)	991,000
Subtotal direct investment	4,813,000
Engineering design	385,000
Contractor fees and overhead	581,000
Contingency allowance	481,000
Subtotal fixed investment	6,260,000
28-14-0 Fertilizer Manufacture	
Yard, utilities, and storage facilities (raw materials storage, railroad unloading and shipping, utilities distribution)	2,356,000
Nitric acid plant (60% nitric acid)	4,000,000
Extraction-filtration (equipment for acidification of phosphate rock, ammonium sulfate addition, and gypsum filtration)	1,360,000
Neutralization-prilling (equipment for neutralization, evaporation prilling, screening, and conveying product)	4,760,000
Bulk storage (storage and shipping buildings, 90 days' storage)	2,530,000
Waste disposal (gypsum and residual ash disposal system including settling pond and land)	275,000
Subtotal direct investment	15,281,000
Engineering design	1,222,000
Contractor fees and overhead	1,839,000
Contingency allowance	1,528,000
Subtotal fixed investment	19,870,000
Total fixed investment for project	26,130,000
Investment savings for 99% effective electrostatic precipitator	(905,000)
Net fixed investment for project assuming precipitator savings	25,225,000

[a] Basis:
Stack gas reheat to 250° F. by indirect gas-liquid method.
Direct solids disposal as 10% slurry (no return of water but overflow neutralized).
Disposal pond distance of 1 mile.
Midwest plant location—1969 costs.

Table B-6. Summary of Estimated Fixed Investment:[a]
Process A—Ammonia Scrubbing, 28-14-0 Fertilizer Manufacture

(1000-mw new power unit, 3.5% S in coal; 86.8 tons/hr fertilizer)

	Investment, $
Ammonia Scrubbing	
Utilities and storage (ammonia storage and utilities distribution systems)	315,000
Scrubbers and fans (four 4-stage scrubbers with mist eliminators, exhaust fans to stack, and pumps)	3,340,000
Stack gas reheat system (8 gas-liquid heat exchangers and circulating pumps)	2,500,000
Oxidizer system (sulfiter, solution storage, oxidizer, and pumps)	1,255,000
Subtotal direct investment	7,410,000
Engineering design	519,000
Contractor fees and overhead	741,000
Contingency allowance	590,000
Subtotal fixed investment	9,260,000
28-14-0 Fertilizer Manufacture	
Yard, utilities, and storage facilities (raw materials storage, railroad unloading and shipping, utilities distribution)	2,831,000
Nitric acid plant (60% nitric acid)	4,480,000
Extraction-filtration (equipment for acidification of phosphate rock, ammonium sulfate addition, and gypsum filtration)	1,660,000
Neutralization-prilling (equipment for neutralization, evaporation prilling, screening, and conveying product)	7,600,000
Bulk storage (storage and shipping buildings, 90 days' storage)	3,320,000
Waste disposal (gypsum and residual ash disposal system including settling pond and land)	301,000
Subtotal direct investment	20,192,000
Engineering design	1,413,000
Contractor fees and overhead	2,019,000
Contingency allowance	1,616,000
Subtotal fixed investment	25,240,000
Total fixed investment for project	34,500,000
Investment savings for 99% effective electrostatic precipitator	(1,550,000)
Net fixed investment for project assuming precipitator savings	32,950,000

[a] Basis:
Stack gas reheat to 250°F. by indirect gas-liquid method.
Direct solids disposal as 10% slurry (no return of water but overflow neutralized).
Disposal pond distance of 1 mile.
Midwest plant location—1969 costs.

Table B-7. Summary of Estimated Fixed Investment:[a] Process A—Ammonia Scrubbing, 28-14-0 Fertilizer Manufacture

(1000-mw existing power unit, 3.5% S in coal; 86.8 tons/hr fertilizer)

	Investment, $
Ammonia Scrubbing	
Utilities and storage (ammonia storage and utilities distribution systems)	350,000
Scrubbers and fans (four 3-stage scrubbers with mist eliminators, exhaust fans to stack, and pumps)	3,500,000
Stack gas reheat system (8 gas-liquid heat exchangers and circulating pumps)	2,500,000
Oxidizer system (sulfiter, solution storage, oxidizer, and pumps)	1,255,000
Subtotal direct investment	7,605,000
Engineering design	608,000
Contractor fees and overhead	917,000
Contingency allowance	760,000
Subtotal fixed investment	9,890,000
28-14-0 Fertilizer Manufacture	
Yard, utilities, and storage facilities (raw materials storage, railroad unloading and shipping, utilities distribution)	3,145,000
Nitric acid plant (60% nitric acid)	4,480,000
Extraction-filtration (equipment for acidification of phosphate rock, ammonium sulfate addition, and gypsum filtration)	1,660,000
Neutralization-prilling (equipment for neutralization, evaporation prilling, screening, and conveying product)	7,600,000
Bulk storage (storage and shipping buildings, 90 days' storage)	3,320,000
Waste disposal (gypsum and residual ash disposal system including settling pond and land)	301,000
Subtotal direct investment	20,506,000
Engineering design	1,640,000
Contractor fees and overhead	2,463,000
Contingency allowance	2,051,000
Subtotal fixed investment	26,660,000
Total fixed investment for project	36,550,000

[a] Basis:
Stack gas reheat to 250° F. by indirect gas-liquid method.
Direct solids disposal as 10% slurry (no return of water but overflow neutralized).
Disposal pond distance of 1 mile.
Midwest plant location—1969 costs.

Table B-8. Summary of Estimated Fixed Investment:[a] Process B—Ammonia Scrubbing, 26-19-0 Fertilizer Manufacture

(200-mw existing power unit, 3.5% S in coal;
13.1 tons/hr fertilizer)

	Investment, $
Ammonia Scrubbing	
Utilities and storage (ammonia storage and utilities distribution systems)	101,000
Scrubbers and fans (two 4-stage scrubbers with mist eliminators, exhaust fans to stack, pumps, and ash disposal)	1,015,000
Stack gas reheat system (4 gas-liquid heat exchangers and circulating pumps)	670,000
Acidifier system (solution storage, stripper, and pumps)	165,000
Subtotal direct investment	1,951,000
Engineering design	195,000
Contractor fees and overhead	293,000
Contingency allowance	195,000
Subtotal fixed investment	2,634,000
26-19-0 Fertilizer Manufacture	
Yard, utilities, and storage facilities (raw materials storage, railroad unloading and shipping, utilities distribution)	909,000
Sulfuric acid plant for sulfur dioxide feed (93% acid)	720,000
Nitric acid plant (60% nitric acid)	1,450,000
Extraction-filtration (equipment for acidification of phosphate rock, ammonium sulfate addition, and gypsum filtration)	760,000
Neutralization-prilling (equipment for neutralization, evaporation prilling, screening, and conveying product)	1,800,000
Bulk storage (storage and shipping buildings, 90 days' storage)	670,000
Waste disposal (gypsum and residual ash disposal system including settling pond and land)	206,000
Subtotal direct investment	6,515,000
Engineering design	651,000
Contractor fees and overhead	977,000
Contingency allowance	651,000
Subtotal fixed investment	8,794,000
Total fixed investment for project	11,428,000

[a] Basis:
Stack gas reheat to 250° F. by indirect gas-liquid method.
Direct solids disposal as 10% slurry (no return of water but overflow neutralized).
Disposal pond distance of 1 mile.
Midwest plant location–1969 costs.

Table B-9. Summary of Estimated Fixed Investment:[a] Process B—Ammonia Scrubbing, 26-19-0 Fertilizer Manufacture

(500-mw new power unit, 2.0% S in coal;
18.7 tons/hr fertilizer)

	Investment, $
Ammonia Scrubbing	
Utilities and storage (ammonia storage and utilities distribution systems)	123,000
Scrubbers and fans (four 5-stage scrubbers with mist eliminators, exhaust fans to stack, pumps, and ash disposal)	2,295,000
Stack gas reheat system (8 gas-liquid heat exchangers and circulating pumps)	1,500,000
Acidifier system (solution storage, stripper, and pumps)	220,000
Subtotal direct investment	4,138,000
Engineering design	331,000
Contractor fees and overhead	497,000
Contingency allowance	414,000
Subtotal fixed investment	5,380,000
26-19-0 Fertilizer Manufacture	
Yard, utilities, and storage facilities (raw materials storage, railroad unloading and shipping, utilities distribution)	1,112,000
Sulfuric acid plant for sulfur dioxide feed (93% acid)	890,000
Nitric acid plant (60% nitric acid)	1,800,000
Extraction-filtration (equipment for acidification of phosphate rock, ammonium sulfate addition, and gypsum filtration)	820,000
Neutralization-prilling (equipment for neutralization, evaporation prilling, screening, and conveying product)	2,220,000
Bulk storage (storage and shipping buildings, 90 days' storage)	775,000
Waste disposal (gypsum and residual ash disposal system including settling pond and land)	225,000
Subtotal direct investment	7,842,000
Engineering design	627,000
Contractor fees and overhead	941,000
Contingency allowance	784,000
Subtotal fixed investment	10,194,000
Total fixed investment for project	15,574,000
Investment savings for 99% effective electrostatic precipitator	(905,000)
Net fixed investment for project assuming precipitator savings	14,669,000

[a] Basis:
Stack gas reheat to 250°F. by indirect gas-liquid method.
Direct solids disposal as 10% slurry (no return of water but overflow neutralized).
Disposal pond distance of 1 mile.
Midwest plant location—1969 costs.

Table B-10. Summary of Estimated Fixed Investment:[a] Process B—Ammonia Scrubbing, 26-19-0 Fertilizer Manufacture

(500-mw new power unit, 3.5% S in coal;
32.8 tons/hr fertilizer)

	Investment, $
Ammonia Scrubbing	
Utilities and storage (ammonia storage and utilities distribution systems)	175,000
Scrubbers and fans (four 5-stage scrubbers with mist eliminators, exhaust fans to stack, pumps, and ash disposal)	2,295,000
Stack gas reheat system (8 gas-liquid heat exchangers and circulating pumps)	1,500,000
Acidifier system (solution storage, stripper, and pumps)	308,000
Subtotal direct investment	4,278,000
Engineering design	342,000
Contractor fees and overhead	513,000
Contingency allowance	428,000
Subtotal fixed investment	5,561,000
26-19-0 Fertilizer Manufacture	
Yard, utilities,and storage facilities (raw materials storage, railroad unloading and shipping, utilities distribution)	1,575,000
Sulfuric acid plant for sulfur dioxide feed (93% acid)	970,000
Nitric acid plant (60% nitric acid)	2,650,000
Extraction-filtration (equipment for acidification of phosphate rock, ammonium sulfate addition, and gypsum filtration)	925,000
Neutralization-prilling (equipment for neutralization, evaporation prilling, screening, and conveying product)	3,150,000
Bulk storage (storage and shipping buildings, 90 days' storage)	1,355,000
Waste disposal (gypsum and residual ash disposal system including settling pond and land)	243,000
Subtotal direct investment	10,868,000
Engineering design	869,000
Contractor fees and overhead	1,304,000
Contingency allowance	1,087,000
Subtotal fixed investment	14,128,000
Total fixed investment for project	19,689,000
Investment savings for 99% effective electrostatic precipitator	(905,000)
Net fixed investment for project assuming precipitator savings	18,784,000

[a] Basis:
Stack gas reheat to 250° F. by indirect gas-liquid method.
Direct solids disposal as 10% slurry (no return of water but overflow neutralized).
Disposal pond distance of 1 mile.
Midwest plant location—1969 costs.

Table B-11. Summary of Estimated Fixed Investment:[a] Process B—Ammonia Scrubbing, 26-19-0 Fertilizer Manufacture

(500-mw existing power unit, 3.5% S in coal; 32.8 tons/hr fertilizer)

	Investment, $
Ammonia Scrubbing	
Utilities and storage (ammonia storage and utilities distribution systems)	158,000
Scrubbers and fans (four 4-stage scrubbers with mist eliminators, exhaust fans to stack, pumps, and ash disposal)	2,375,000
Stack gas reheat system (8 gas-liquid heat exchangers and circulating pumps)	1,500,000
Acidifier system (solution storage, stripper, and pumps)	308,000
Subtotal direct investment	4,341,000
Engineering design	434,000
Contractor fees and overhead	651,000
Contingency allowance	434,000
Subtotal fixed investment	5,860,000
26-19-0 Fertilizer Manufacture	
Yard, utilities, and storage facilities (raw materials storage, railroad unloading and shipping, utilities distribution)	1,322,000
Sulfuric acid plant for sulfur dioxide feed (93% acid)	970,000
Nitric acid plant (60% nitric acid)	2,650,000
Extraction-filtration (equipment for acidification of phosphate rock, ammonium sulfate addition, and gypsum filtration)	925,000
Neutralization-prilling (equipment for neutralization, evaporation prilling, screening, and conveying product)	3,150,000
Bulk storage (storage and shipping buildings, 90 days' storage)	1,355,000
Waste disposal (gypsum and residual ash disposal system including settling pond and land)	243,000
Subtotal direct investment	10,615,000
Engineering design	1,062,000
Contractor fees and overhead	1,592,000
Contingency allowance	1,062,000
Subtotal fixed investment	14,331,000
Total fixed investment for project	20,191,000

[a] Basis:
Stack gas reheat to 250°F. by indirect gas-liquid method.
Direct solids disposal as 10% slurry (no return of water but overflow neutralized).
Disposal pond distance of 1 mile.
Midwest plant location—1969 costs.

Table B-12. Summary of Estimated Fixed Investment:[a] Process B—Ammonia Scrubbing, 26-19-0 Fertilizer Manufacture

(500-mw new power unit, 5.0% S in coal;
46.9 tons/hr fertilizer)

	Investment, $
Ammonia Scrubbing	
Utilities and storage (ammonia storage and utilities distribution systems)	216,000
Scrubbers and fans (four 5-stage scrubbers with mist eliminators, exhaust fans to stack, pumps, and ash disposal)	2,295,000
Stack gas reheat system (8 gas-liquid heat exchangers and circulating pumps)	1,500,000
Acidifier system (solution storage, stripper, and pumps)	385,000
Subtotal direct investment	4,396,000
Engineering design	352,000
Contractor fees and overhead	528,000
Contingency allowance	440,000
Subtotal fixed investment	5,716,000
26-19-0 Fertilizer Manufacture	
Yard, utilities,and storage facilities (raw materials storage, railroad unloading and shipping, utilities distribution)	1,944,000
Sulfuric acid plant for sulfur dioxide feed (93% acid)	1,200,000
Nitric acid plant (60% nitric acid)	3,300,000
Extraction-filtration (equipment for acidification of phosphate rock, ammonium sulfate addition, and gypsum filtration)	1,140,000
Neutralization-prilling (equipment for neutralization, evaporation prilling, screening, and conveying product)	3,900,000
Bulk storage (storage and shipping buildings, 90 days' storage)	1,940,000
Waste disposal (gypsum and residual ash disposal system including settling pond and land)	275,000
Subtotal direct investment	13,699,000
Engineering design	1,096,000
Contractor fees and overhead	1,644,000
Contingency allowance	1,370,000
Subtotal fixed investment	17,809,000
Total fixed investment for project	23,525,000
Investment savings for 99% effective electrostatic precipitator	(905,000)
Net fixed investment for project assuming precipitator savings	22,620,000

[a] Basis:
Stack gas reheat to 250°F. by indirect gas-liquid method.
Direct solids disposal as 10% slurry (no return of water but overflow neutralized).
Disposal pond distance of 1 mile.
Midwest plant location—1969 costs.

Table B-13. Summary of Estimated Fixed Investment:[a] Process B—Ammonia Scrubbing, 26-19-0 Fertilizer Manufacture

(1000-mw new power unit, 3.5% S in coal;
65.7 tons/hr fertilizer)

	Investment, $
Ammonia Scrubbing	
Utilities and storage (ammonia storage and utilities distribution systems)	242,000
Scrubbers and fans (four 5-stage scrubbers with mist eliminators, exhaust fans to stack, pumps, and ash disposal)	3,610,000
Stack gas reheat system (8 gas-liquid heat exchangers and circulating pumps)	2,500,000
Acidifier system (solution storage, stripper, and pumps)	500,000
Subtotal direct investment	6,852,000
Engineering design	480,000
Contractor fees and overhead	685,000
Contingency allowance	548,000
Subtotal fixed investment	8,565,000
26-19-0 Fertilizer Manufacture	
Yard, utilities, and storage facilities (raw materials storage, railroad unloading and shipping, utilities distribution)	2,178,000
Sulfuric acid plant for sulfur dioxide feed (93% acid)	1,390,000
Nitric acid plant (60% nitric acid)	3,820,000
Extraction-filtration (equipment for acidification of phosphate rock, ammonium sulfate addition, and gypsum filtration)	1,400,000
Neutralization-prilling (equipment for neutralization, evaporation prilling, screening, and conveying product)	6,300,000
Bulk storage (storage and shipping buildings, 90 days' storage)	2,560,000
Waste disposal (gypsum and residual ash disposal system including settling pond and land)	301,000
Subtotal direct investment	17,949,000
Engineering design	1,256,000
Contractor fees and overhead	1,795,000
Contingency allowance	1,435,000
Subtotal fixed investment	22,435,000
Total fixed investment for project	31,000,000
Investment savings for 99% effective electrostatic precipitator	(1,550,000)
Net fixed investment for project assuming precipitator savings	29,450,000

[a] Basis:
Stack gas reheat to 250°F. by indirect gas-liquid method.
Direct solids disposal as 10% slurry (no return of water but overflow neutralized).
Disposal pond distance of 1 mile.
Midwest plant location—1969 costs.

Table B-14. Summary of Estimated Fixed Investment:[a]
Process B—Ammonia Scrubbing, 26-19-0 Fertilizer Manufacture

(1000-mw existing power unit, 3.5% S in coal;
65.7 tons/hr fertilizer)

	Investment, $
Ammonia Scrubbing	
Utilities and storage (ammonia storage and utilities distribution systems)	269,000
Scrubbers and fans (four 4-stage scrubbers with mist eliminators, exhaust fans to stack, pumps, and ash disposal)	3,850,000
Stack gas reheat system (8 gas-liquid heat exchangers and circulating pumps)	2,500,000
Acidifier system (solution storage, stripper, and pumps)	500,000
Subtotal direct investment	7,119,000
Engineering design	570,000
Contractor fees and overhead	854,000
Contingency allowance	712,000
Subtotal fixed investment	9,255,000
26-19-0 Fertilizer Manufacture	
Yard, utilities and storage facilities (raw materials storage, railroad unloading and shipping, utilities distribution)	2,421,000
Sulfuric acid plant for sulfur dioxide feed (93% acid)	1,390,000
Nitric acid plant (60% nitric acid)	3,820,000
Extraction-filtration (equipment for acidification of phosphate rock, ammonium sulfate addition, and gypsum filtration)	1,400,000
Neutralization-prilling (equipment for neutralization, evaporation prilling, screening, and conveying product)	6,300,000
Bulk storage (storage and shipping buildings, 90 days' storage)	2,560,000
Waste disposal (gypsum and residual ash disposal system including settling pond and land)	301,000
Subtotal direct investment	18,192,000
Engineering design	1,455,000
Contractor fees and overhead	2,183,000
Contingency allowance	1,819,000
Subtotal fixed investment	23,749,000
Total fixed investment for project	32,904,000

[a] Basis:
Stack gas reheat to 250°F. by indirect gas-liquid method.
Direct solids disposal as 10% slurry (no return of water but overflow neutralized).
Disposal pond distance of 1 mile.
Midwest plant location – 1969 costs.

Table B-15. Summary of Estimated Fixed Investment:[a]
Process C—Ammonia Scrubbing, 19-14-0 Fertilizer Manufacture

(200-mw existing power unit, 3.5% S in coal;
8.1 tons/hr fertilizer)

	Investment, $
Ammonia Scrubbing	
Utilities and storage (ammonia storage and utilities distribution systems)	71,000
Scrubbers and fans (two 3-stage scrubbers with mist eliminators, exhaust fans to stack, pumps, and ash disposal)	925,000
Stack gas reheat system (four gas-liquid heat exchangers and circulating pumps)	670,000
Oxidizer system (solution storage, oxidizer, sulfiter, filter, and pumps)	467,000
Subtotal direct investment	2,133,000
Engineering design	213,000
Contractor fees and overhead	321,000
Contingency allowance	213,000
Subtotal fixed investment	2,880,000
19-14-0 Fertilizer Manufacture	
Yard, utilities, and storage facilities (raw materials storage, railroad unloading and shipping, utilities distribution)	639,000
Crystallization-decomposition (double effect crystallizers, centrifuge, decomposer, and solubilizing tank with heat supply and reclamation system, and ammonium bisulfate solution storage)	2,295,000
Extraction-filtration (equipment for acidification of phosphate rock by ammonium bisulfate addition and gypsum filtration)	790,000
Neutralization-granulation (equipment for neutralization, granulation, recycle, screening, and conveying product)	625,000
Bulk storage (storage and shipping buildings, 60 days' storage)	450,000
Waste disposal (gypsum and residual ash disposal system including settling pond and land)	171,000
Subtotal direct investment	4,970,000
Engineering design	497,000
Contractor fees and overhead	745,500
Contingency allowance	497,000
Subtotal fixed investment	6,709,500
Total fixed investment for project	9,589,500

[a] Basis:
Stack gas reheat to 250°F. by indirect gas-liquid method.
Direct solids disposal as 10% slurry (no return of water but overflow neutralized).
Disposal pond distance of 1 mile
Midwest plant location—1969 costs.

Table B-16. Summary of Estimated Fixed Investment:[a] Process C—Ammonia Scrubbing, 19-14-0 Fertilizer Manufacture

(500-mw new power unit, 2.0% S in coal;
10.9 tons/hr fertilizer)

	Investment, $
Ammonia Scrubbing	
Utilities and storage (ammonia storage and utilities distribution systems)	87,000
Scrubbers and fans (four 4-stage scrubbers with mist eliminators, exhaust fans to stack, pumps, and ash disposal)	2,060,000
Stack gas reheat system (eight gas-liquid heat exchangers and circulating pumps)	1,500,000
Oxidizer system (solution storage, oxidizer, sulfiter, filter, and pumps)	596,000
Subtotal direct investment	4,243,000
Engineering design	340,000
Contractor fees and overhead	509,000
Contingency allowance	424,000
Subtotal fixed investment	5,516,000
19-14-0 Fertilizer Manufacture	
Yard, utilities, and storage facilities (raw materials storage, railroad unloading and shipping, utilities distribution)	781,000
Crystallization-decomposition (double effect crystallizers, centrifuge, decomposer, and solubilizing tank with heat supply and reclamation system, and ammonium bisulfate solution storage)	2,653,000
Extraction-filtration (equipment for acidification of phosphate rock by ammonium bisulfate addition and gypsum filtration)	825,000
Neutralization-granulation (equipment for neutralization, granulation, recycle, screening, and conveying product)	760,000
Bulk storage (storage and shipping buildings, 60 days' storage)	600,000
Waste disposal (gypsum and residual ash disposal system including settling pond and land)	182,000
Subtotal direct investment	5,801,000
Engineering design	464,100
Contractor fees and overhead	696,100
Contingency allowance	580,100
Subtotal fixed investment	7,541,300
Total fixed investment for project	13,057,300
Investment savings for 99% effective electrostatic precipitator	(905,000)
Net fixed investment for project assuming precipitator savings	12,152,300

[a] Basis:
Stack gas reheat to 250°F. by indirect gas-liquid method.
Direct solids disposal as 10% slurry (no return of water but overflow neutralized).
Disposal pond distance of 1 mile.
Midwest plant location—1969 costs.

Table B-17. Summary of Estimated Fixed Investment:[a] Process C—Ammonia Scrubbing, 19-14-0 Fertilizer Manufacture

(500-mw new power unit, 3.5% S in coal; 19.2 tons/hr fertilizer)

	Investment, $
Ammonia Scrubbing	
Utilities and storage (ammonia storage and utilities distribution systems)	123,000
Scrubbers and fans (four 4-stage scrubbers with mist eliminators, exhaust fans to stack, pumps, and ash disposal)	2,060,000
Stack gas reheat system (eight gas-liquid heat exchangers and circulating pumps)	1,500,000
Oxidizer system (solution storage, oxidizer, sulfiter, filter, and pumps)	883,000
Subtotal direct investment	4,566,000
Engineering design	365,000
Contractor fees and overhead	548,000
Contingency allowance	457,000
Subtotal fixed investment	5,936,000
19-14-0 Fertilizer Manufacture	
Yard, utilities, and storage facilities (raw materials storage, railroad unloading and shipping, utilities distribution)	1,107,000
Crystallization-decomposition (double effect crystallizers, centrifuge, decomposer, and solubilizing tank with heat supply and reclamation system, and ammonium bisulfate solution storage)	3,812,000
Extraction-filtration (equipment for acidification of phosphate rock by ammonium bisulfate addition and gypsum filtration)	900,000
Neutralization-granulation (equipment for neutralization, granulation, recycle, screening, and conveying product)	1,100,000
Bulk storage (storage and shipping buildings, 60 days' storage)	940,000
Waste disposal (gypsum and residual ash disposal system including settling pond and land)	193,000
Subtotal direct investment	8,052,000
Engineering design	644,200
Contractor fees and overhead	966,200
Contingency allowance	805,200
Subtotal fixed investment	10,420,600
Total fixed investment for project	16,356,600
Investment savings for 99% effective electrostatic precipitator	(905,000)
Net fixed investment for project assuming precipitator savings	15,451,600

[a] Basis:
Stack gas reheat to 250° F. by indirect gas-liquid method.
Direct solids disposal as 10% slurry (no return of water but overflow neutralized).
Disposal pond distance of 1 mile.
Midwest plant location–1969 costs.

Table B-18. Summary of Estimated Fixed Investment:[a] Process C—Ammonia Scrubbing, 19-14-0 Fertilizer Manufacture

(500-mw existing power unit, 3.5% S in coal;
19.6 tons/hr fertilizer)

	Investment, $
Ammonia Scrubbing	
Utilities and storage (ammonia storage and utilities distribution systems)	111,000
Scrubbers and fans (four 3-stage scrubbers with mist eliminators, exhaust fans to stack, pumps, and ash disposal)	2,150,000
Stack gas reheat system (eight gas-liquid heat exchangers and circulating pumps)	1,500,000
Oxidizer system (solution storage, oxidizer, sulfiter, filter, and pumps)	883,000
Subtotal direct investment	4,644,000
Engineering design	464,000
Contractor fees and overhead	697,000
Contingency allowance	464,000
Subtotal fixed investment	6,269,000
19-14-0 Fertilizer Manufacture	
Yard, utilities, and storage facilities (raw materials storage, railroad unloading and shipping, utilities distribution)	999,000
Crystallization-decomposition (double effect crystallizers, centrifuge, decomposer, and solubilizing tank with heat supply and reclamation system, and ammonium bisulfate solution storage)	4,064,000
Extraction-filtration (equipment for acidification of phosphate rock by ammonium bisulfate addition and gypsum filtration)	900,000
Neutralization-granulation (equipment for neutralization, granulation, recycle, screening, and conveying product)	1,100,000
Bulk storage (storage and shipping buildings, 60 days' storage)	940,000
Waste disposal (gypsum and residual ash disposal system including settling pond and land)	193,000
Subtotal direct investment	8,193,000
Engineering design	819,300
Contractor fees and overhead	1,229,000
Contingency allowance	819,300
Subtotal fixed investment	11,060,600
Total fixed investment for project	17,329,600

[a] Basis:
Stack gas reheat to 250° F. by indirect gas-liquid method.
Direct solids disposal as 10% slurry (no return of water but overflow neutralized).
Disposal pond distance of 1 mile.
Midwest plant location–1969 costs.

Table B-19. Summary of Estimated Fixed Investment:[a] Process C—Ammonia Scrubbing, 19-14-0 Fertilizer Manufacture

(500-mw new power unit, 5.0% S in coal; 27.3 tons/hr fertilizer)

	Investment, $
Ammonia Scrubbing	
Utilities and storage (ammonia storage and utilities distribution systems)	152,000
Scrubbers and fans (four 4-stage scrubbers with mist eliminators, exhaust fans to stack, pumps, and ash disposal)	2,060,000
Stack gas reheat system (eight gas-liquid heat exchangers and circulating pumps)	1,500,000
Oxidizer system (solution storage, oxidizer, sulfiter, filter, and pumps)	1,140,000
Subtotal direct investment	4,852,000
Engineering design	388,000
Contractor fees and overhead	582,000
Contingency allowance	485,000
Subtotal fixed investment	6,307,000
19-14-0 Fertilizer Manufacture	
Yard, utilities, and storage facilities (raw materials storage, railroad unloading and shipping, utilities distribution)	1,368,000
Crystallization-decomposition (double effect crystallizers, centrifuge, decomposer, and solubilizing tank with heat supply and reclamation system, and ammonium bisulfate solution storage)	4,811,000
Extraction-filtration (equipment for acidification of phosphate rock by ammonium bisulfate addition and gypsum filtration)	1,000,000
Neutralization-granulation (equipment for neutralization, granulation, recycle, screening, and conveying product)	1,390,000
Bulk storage (storage and shipping buildings, 60 days' storage)	1,230,000
Waste disposal (gypsum and residual ash disposal system including settling pond and land)	212,000
Subtotal direct investment	10,011,000
Engineering design	800,900
Contractor fees and overhead	1,201,300
Contingency allowance	1,001,100
Subtotal fixed investment	13,014,300
Total fixed investment for project	19,321,300
Investment savings for 99% effective electrostatic precipitator	(905,000)
Net fixed investment for project assuming precipitator savings	18,416,300

[a] Basis:
Stack gas reheat to 250°F. by indirect gas-liquid method.
Direct solids disposal as 10% slurry (no return of water but overflow neutralized).
Disposal pond distance of 1 mile.
Midwest plant location–1969 costs.

Table B-20. Summary of Estimated Fixed Investment:[a] Process C—Ammonia Scrubbing, 19-14-0 Fertilizer Manufacture

(1000-mw new power unit, 3.5% S in coal; 37.1 tons/hr fertilizer)

	Investment, $
Ammonia Scrubbing	
Utilities and storage (ammonia storage and utilities distribution systems)	170,000
Scrubbers and fans (four 4-stage scrubbers with mist eliminators, exhaust fans to stack, pumps, and ash disposal)	3,340,000
Stack gas reheat system (eight gas-liquid heat exchangers and circulating pumps)	2,500,000
Oxidizer system (solution storage, oxidizer, sulfiter, filter, and pumps)	1,440,000
Subtotal direct investment	7,450,000
Engineering design	522,000
Contractor fees and overhead	745,000
Contingency allowance	596,000
Subtotal fixed investment	9,313,000
19-14-0 Fertilizer Manufacture	
Yard, utilities, and storage facilities (raw materials storage, railroad unloading and shipping, utilities distribution)	1,530,000
Crystallization-decomposition (double effect crystallizers, centrifuge, decomposer, and solubilizing tank with heat supply and reclamation system, and ammonium bisulfate solution storage)	5,863,000
Extraction-filtration (equipment for acidification of phosphate rock by ammonium bisulfate addition and gypsum filtration)	1,100,000
Neutralization-granulation (equipment for neutralization, granulation, recycle, screening, and conveying product)	1,870,000
Bulk storage (storage and shipping buildings, 60 days' storage)	1,670,000
Waste disposal (gypsum and residual ash disposal system including settling pond and land)	228,000
Subtotal direct investment	12,261,000
Engineering design	858,300
Contractor fees and overhead	1,226,100
Contingency allowance	980,900
Subtotal fixed investment	15,326,300
Total fixed investment for project	24,639,300
Investment savings for 99% effective electrostatic precipitator	(1,550,000)
Net fixed investment for project assuming precipitator savings	23,089,300

[a] Basis:
Stack gas reheat to 250°F. by indirect gas-liquid method.
Direct solids disposal as 10% slurry (no return of water but overflow neutralized).
Disposal pond distance of 1 mile.
Midwest plant location–1969 costs.

Table B-21. Summary of Estimated Fixed Investment:[a] Process C—Ammonia Scrubbing, 19-14-0 Fertilizer Manufacture

(1000-mw existing power unit, 3.5% S in coal; 38.3 tons/hr fertilizer)

	Investment, $
Ammonia Scrubbing	
Utilities and storage (ammonia storage and utilities distribution systems)	189,000
Scrubbers and fans (four 3-stage scrubbers with mist eliminators, exhaust fans to stack, pumps, and ash disposal)	3,500,000
Stack gas reheat system (eight gas-liquid heat exchangers and circulating pumps)	2,500,000
Oxidizer system (solution storage, oxidizer, sulfiter, filter, and pumps)	1,440,000
Subtotal direct investment	7,629,000
Engineering design	610,000
Contractor fees and overhead	916,000
Contingency allowance	763,000
Subtotal fixed investment	9,918,000
19-14-0 Fertilizer Manufacture	
Yard, utilities, and storage facilities (raw materials storage, railroad unloading and shipping, utilities distribution)	1,701,000
Crystallization-decomposition (double effect crystallizers, centrifuge, decomposer, and solubilizing tank with heat supply and reclamation system, and ammonium bisulfate solution storage)	6,299,000
Extraction-filtration (equipment for acidification of phosphate rock by ammonium bisulfate addition and gypsum filtration)	1,100,000
Neutralization-granulation (equipment for neutralization, granulation, recycle, screening, and conveying product)	1,870,000
Bulk storage (storage and shipping buildings, 60 days' storage)	1,670,000
Waste disposal (gypsum and residual ash disposal system including settling pond and land)	228,000
Subtotal direct investment	12,868,000
Engineering design	1,029,400
Contractor fees and overhead	1,544,200
Contingency allowance	1,286,800
Subtotal fixed investment	16,728,400
Total fixed investment for project	26,646,400

[a] Basis:
Stack gas reheat to 250°F. by indirect gas-liquid method.
Direct solids disposal as 10% slurry (no return of water but overflow neutralized).
Disposal pond distance of 1 mile.
Midwest plant location—1969 costs.

Table B-22. Fertilizer Company Economics - Total Venture Annual Manufacturing Costs for 28-14-0 Fertilizer Made with Ammonium Sulfate Solution Obtained by Scrubbing Power Plant Stack Gas[a]—Process A

(200-mw existing power unit, 3.5% S in coal; 128,600 tons/yr fertilizer)

	Annual quantity	Unit cost, $	Total annual cost, $	$/ton of fertilizer
Direct Costs				
Delivered raw material				
Ammonia	45.5 M tons	35.00/ton	1,592,200	12.385
Phosphate rock	60.9 M tons	12.88/ton	784,400	6.100
Conditioner	2.5 M tons	46.60/ton	117,900	0.917
Antifoam	48.8 M lb	0.20/lb	9,800	0.076
Nitric acid catalyst	243 troy oz	120/troy oz	28,900	0.225
Subtotal raw material			2,533,200	19.703
Conversion costs				
Operating labor and supervision	70,000 man-hr	4.50/man-hr	315,000	2.449
Utilities				
Steam	471,200 M lb	0.60/M lb	282,700	2.198
Water	3,159,600 M gal	0.06/M gal	189,600	1.474
Electricity	36,617,000 kwh	0.006/kwh[b]	219,700	1.708
Maintenance				
Labor and material			564,400	4.389
Analyses			36,000	0.280
Subtotal conversion costs			1,607,400	12.498
Subtotal direct costs			4,140,600	32.201
Indirect Costs				
Depreciation at 10% of fixed investment			1,250,000	9.720
Local taxes and insurance at 2% of fixed investment			250,000	1.944
Overhead				
Plant, 20% of conversion costs			321,500	2.500
Administrative, research, and service, 7% of conversion costs			112,500	0.875
Subtotal indirect costs			1,934,000	15.039
Total annual manufacturing costs for 28-14-0 fertilizer			6,074,600	47.240

[a] Basis:
Remaining life of power plant–27 years.
Coal burned–554,400 tons/yr–0.792 lb/kwh.
Power unit operating stream time–7,000 hr/yr. Fertilizer plant on-stream time–7,000 hr/yr.
Stack gas reheat from 118° to 250° F., indirect liquid-gas method.
Midwest plant location–1969 costs.
Capital investment–$12,520,000 fixed; $875,000 working.

[b] Cost of electricity at power plant bus bar.

Table B-23. Fertilizer Company Economics - Total Venture Annual Manufacturing Costs for 28-14-0 Fertilizer Made with Ammonium Sulfate Solution Obtained by Scrubbing Power Plant Stack Gas[a]—Process A

(500-mw new power unit, 2.0% S in coal; 173,600 tons/yr fertilizer)

	Annual quantity	Unit cost, $	Total annual cost, $	$/ton of fertilizer
Direct Costs				
Delivered raw material				
Ammonia	61.4 M tons	35.00/ton	2,150,000	12.385
Phosphate rock	82.2 M tons	12.48/ton	1,025,900	5.910
Conditioner	3.4 M tons	46.60/ton	159,700	0.920
Antifoam	65.8 M lb	0.20/lb	13,600	0.076
Nitric acid catalyst	325 troy oz	120/troy oz	39,000	0.225
Subtotal raw material			3,388,200	19.516
Conversion costs				
Operating labor and supervision	76,000 man-hr	4.50/man-hr	342,000	1.970
Utilities				
Steam	640,290 M lb	0.40/M lb[b]	256,100	1.475
Water	4,279,000 M gal	0.05/M gal	214,000	1.232
Electricity	63,147,000 kwh	0.005/kwh[c]	315,700	1.819
Maintenance				
Labor and material			751,000	4.327
Analyses			43,000	0.248
Subtotal conversion costs			1,921,800	11.071
Subtotal direct costs			5,310,000	30.587
Indirect Costs				
Depreciation at 10% of fixed investment			1,669,500	9.616
Local taxes and insurance at 2% of fixed investment			333,900	1.923
Overhead				
Plant, 20% of conversion costs			384,400	2.214
Administrative, research, and service, 7% of conversion costs			134,500	0.775
Subtotal indirect costs			2,522,300	14.528
Total annual manufacturing costs for 28-14-0 fertilizer			7,832,300	45.115

[a] Basis:
Remaining life of power plant - 35 years.
Coal burned - 1,310,000 tons/yr.
Power unit operating stream time - 7,000 hr/yr. Fertilizer plant on-stream time - 7,000 hr/yr.
Stack gas reheat from 118° to 250° F., indirect liquid-gas method.
Midwest plant location - 1969 costs.
Capital investment - $16,695,000 fixed; $1,170,800 working.

[b] Cost of steam from power plant cycle.

[c] Cost of electricity at power plant bus bar.

Table B-24. Fertilizer Company Economics - Total Venture Annual Manufacturing Costs for 28-14-0 Fertilizer Made with Ammonium Sulfate Solution Obtained by Scrubbing Power Plant Stack Gas[a]—Process A

(500-mw new power unit, 3.5% S in coal; 303,800 tons/yr fertilizer)

	Annual quantity	Unit cost, $	Total annual cost, $	$/ton of fertilizer
Direct Costs				
Delivered raw material				
Ammonia	107.5 M tons	35.00/ton	3,762,500	12.385
Phosphate rock	143.9 M tons	11.88/ton	1,709,500	5.627
Conditioner	6.0 M tons	46.60/ton	279,600	0.920
Antifoam	115.2 M lb	0.18/lb	20,700	0.068
Nitric acid catalyst	570 troy oz	120/troy oz	68,400	0.225
Subtotal raw material			5,840,700	19.225
Conversion costs				
Operating labor and supervision	98,000 man-hr	4.50/man-hr	441,000	1.452
Utilities				
Steam	1,113,000 M lb	0.40/M lb[b]	448,100	1.475
Water	7,350,000 M gal	0.05/M gal	367,500	1.210
Electricity	82,355,000 kwh	0.005/kwh[c]	411,800	1.355
Maintenance				
Labor and material			966,000	3.180
Analyses			75,000	0.247
Subtotal conversion costs			2,709,400	8.919
Subtotal direct costs			8,550,100	28,144
Indirect Costs				
Depreciation at 10% of fixed investment			2,147,000	7.067
Local taxes and insurance at 2% of fixed investment			429,400	1.413
Overhead				
Plant, 20% of conversion costs			541,900	1.784
Administrative, research, and service, 7% of conversion costs			189,700	0.624
Subtotal indirect costs			3,308,000	10.888
Total annual manufacturing costs for 28-14-0 fertilizer			11,858,100	39.032

[a] Basis:
Remaining life of power plant – 35 years.
Coal burned – 1,310,000 tons/yr.
Power unit operating stream time – 7,000 hr/yr. Fertilizer plant on-stream time – 7,000 hr/yr.
Stack gas reheat from 118° to 250° F., indirect liquid-gas method.
Midwest plant location – 1969 costs.
Capital investment – $21,470,000 fixed; $1,890,500 working.

[b] Cost of steam from power plant cycle.

[c] Cost of electricity at power plant bus bar.

Table B-25. Fertilizer Company Economics - Total Venture Annual Manufacturing Costs for 28-14-0 Fertilizer Made with Ammonium Sulfate Solution Obtained by Scrubbing Power Plant Stack Gas[a]—Process A

(500-mw existing power unit, 3.5% S in coal; 310,800 tons/yr fertilizer)

	Annual quantity	Unit cost, $	Total annual cost, $	$/ton of fertilizer
Direct Costs				
Delivered raw material				
Ammonia	110.0 M tons	35.00/ton	3,850,000	12.385
Phosphate rock	147.2 M tons	11.88/ton	1,748,700	5.627
Conditioner	6.1 M tons	46.60/ton	284,300	0.917
Antifoam	117.8 M lb	0.18/lb	21,200	0.068
Nitric acid catalyst	583 troy oz	120/troy oz	70,000	0.225
Subtotal raw material			5,974,200	19.222
Conversion costs				
Operating labor and supervision	98,500 man-hr	4.50/man-hr	443,300	1.426
Utilities				
Steam	1,137,600 M lb	0.50/M lb	568,800	1.830
Water	7,519,000 M gal	0.06/M gal	451,100	1.451
Electricity	83,405,000 kwh	0.005/kwh[b]	417,000	1.342
Maintenance				
Labor and material			1,000,000	3.218
Analyses			75,000	0.241
Subtotal conversion costs			2,955,200	9.508
Subtotal direct costs			8,929,400	28.730
Indirect Costs				
Depreciation at 10% of fixed investment			2,232,000	7.182
Local taxes and insurance at 2% of fixed investment			446,400	1.436
Overhead				
Plant, 20% of conversion costs			591,000	1.901
Administrative, research, and service, 7% of conversion costs			206,900	0.666
Subtotal indirect costs			3,476,300	11.185
Total annual manufacturing costs for 28-14-0 fertilizer			12,405,700	39.915

[a] Basis:
Remaining life of power plant–32 years.
Coal burned–1,339,600 tons/yr.–0.767 lb/kwh.
Power unit operating stream time–7,000 hr/yr. Fertilizer plant on-stream time–7,000 hr/yr.
Stack gas reheat from 118° to 250° F., indirect liquid-gas method.
Midwest plant location–1969 costs.
Capital investment–$22,320,000 fixed; $1,937,700 working.

[b] Cost of electricity at power plant bus bar.

Table B-26. Fertilizer Company Economics - Total Venture Annual Manufacturing Costs for 28-14-0 Fertilizer Made with Ammonium Sulfate Solution Obtained by Scrubbing Power Plant Stack Gas[a]—Process A

(500-mw new power unit, 5.0% S in coal; 434,000 tons/yr fertilizer)

	Annual quantity	Unit cost, $	Total annual cost, $	$/ton of fertilizer
Direct Costs				
Delivered raw material				
Ammonia	153.9 M tons	30.00/ton	4,618,000	10.640
Phosphate rock	205.6 M tons	11.88/ton	2,442,100	5.627
Conditioner	8.6 M tons	46.60/ton	399,300	0.920
Antifoam	164.2 M lb	0.15/lb	24,600	0.057
Nitric acid catalyst	815 troy oz	120/troy oz	97,800	0.225
Subtotal raw material			7,581,800	17.469
Conversion costs				
Operating labor and supervision	118,000 man-hr	4.50/man-hr	531,000	1.223
Utilities				
Steam	1,670,000 M lb	0.40/M lb[b]	668,000	1.539
Water	9,943,000 M gal	0.04/M gal	397,700	0.916
Electricity	83,475,000 kwh	0.005/kwh[c]	417,400	0.962
Maintenance				
Labor and material			1,125,000	2.592
Analyses			90,000	0.208
Subtotal conversion costs			3,229,100	7.440
Subtotal direct costs			10,810,900	24.909
Indirect Costs				
Depreciation at 10% of fixed investment			2,613,000	6.021
Local taxes and insurance at 2% of fixed investment			522,600	1.204
Overhead				
Plant, 20% of conversion costs			645,800	1.488
Administrative, research, and service, 7% of conversion costs			226,000	0.521
Subtotal indirect costs			4,007,400	9.234
Total annual manufacturing costs for 28-14-0 fertilizer			14,818,300	34.143

[a] Basis:
Remaining life of power plant – 35 years.
Coal burned – 1,310,000 tons/yr.
Power unit operating stream time – 7,000 hr/yr. Fertilizer plant on-stream time – 7,000 hr/yr.
Stack gas reheat from 118° to 250° F., indirect liquid-gas method.
Midwest plant location – 1969 costs.
Capital investment – $26,130,000 fixed; $2,393,100 working.

[b] Cost of steam from power plant cycle.

[c] Cost of electricity at power plant bus bar.

Table B-27. Fertilizer Company Economics - Total Venture Annual Manufacturing Costs for 28-14-0 Fertilizer Made with Ammonium Sulfate Solution Obtained by Scrubbing Power Plant Stack Gas[a]–Process A

(1000-mw new power unit, 3.5% S in coal; 587,500 tons/yr fertilizer)

	Annual quantity	Unit cost, $	Total annual cost, $	$/ton of fertilizer
Direct Costs				
Delivered raw material				
Ammonia	208.4 M tons	30.00/ton	6,252,000	10.642
Phosphate rock	278.3 M tons	11.88/ton	3,306,200	5.627
Conditioner	11.5 M tons	46.60/ton	537,300	0.917
Antifoam	223.4 M lb	0.15/lb	33,500	0.057
Nitric acid catalyst	111.2 troy oz	120/troy oz	133,400	0.225
Subtotal raw material			10,262,400	17.468
Conversion costs				
Operating labor and supervision	135,000 man-hr	4.50/man-hr	607,500	1.034
Utilities				
Steam	2,276,000 M lb	0.30/M lb[b]	682,800	1.162
Water	12,137,000 M gal	0.04/M gal	485,500	0.826
Electricity	133,239,000 kwh	0.004/kwh[c]	533,000	0.907
Maintenance				
Labor and material			1,550,000	2.638
Analyses			120,000	0.204
Subtotal conversion costs			3,978,800	6.771
Subtotal direct costs			14,241,200	24.239
Indirect Costs				
Depreciation at 10% of fixed investment			3,450,000	5.872
Local taxes and insurance at 2% of fixed investment			690,000	1.174
Overhead				
Plant, 20% of conversion costs			795,800	1.354
Administrative, research, and service 7% of conversion costs			278,500	0.474
Subtotal indirect costs			5,214,300	8.874
Total annual manufacturing costs for 28-14-0 fertilizer			19,455,500	33.113

[a] Basis:
Remaining life of power plant–35 years.
Coal burned–2,537,300 tons/yr–0.725 lb/kwh.
Power unit operating stream time–7,000 hr/yr. Fertilizer plant on-stream time–7,000 hr/yr.
Stack gas reheat from 118° to 250° F., indirect liquid-gas method.
Midwest plant location–1969 costs.
Capital investment–$34,500,000 fixed; $3,244,200 working.

[b] Cost of steam from power plant cycle.

[c] Cost of electricity at power plant bus bar.

Table B-28. Fertilizer Company Economics - Total Venture Annual Manufacturing Costs for 28-14-0 Fertilizer Made with Ammonium Sulfate Solution Obtained by Scrubbing Power Plant Stack Gas[a]—Process A

(1000-mw existing power unit, 3.5% S in coal;
607,600 tons/yr fertilizer)

	Annual quantity	Unit cost, $	Total annual cost, $	$/ton of fertilizer
Direct Costs				
Delivered raw material				
Ammonia	215.5 M tons	30.00/ton	6,465,000	10.640
Phosphate rock	288.5 M tons	11.88/ton	3,419,000	5.627
Conditioner	12.0 M tons	46.60/ton	559,200	0.920
Antifoam	231.0 M lb	0.15/lb	34,700	0.057
Nitric acid catalyst	1150 troy oz	120/troy oz	137,000	0.225
Subtotal raw material			10,614,900	17.469
Conversion costs				
Operating labor and supervision	136,000 man-hr	4.50/man-hr	612,000	1.007
Utilities				
Steam	2,354,000 M lb	0.45/M lb	1,059,300	1.744
Water	12,551,000 M gal	0.05/M gal	627,600	1.033
Electricity	135,339,000 kwh	0.004/kwh[b]	541,300	0.891
Maintenance				
Labor and material			1,600,000	2.633
Analyses			120,000	0.197
Subtotal conversion costs			4,560,200	7.505
Subtotal direct costs			15,175,100	24.974
Indirect Costs				
Depreciation at 10% of fixed investment			3,655,000	6.015
Local taxes and insurance at 2% of fixed investment			731,000	1.203
Overhead				
Plant, 20% of conversion costs			912,000	1.501
Administrative, research, and service, 7% of conversion costs			319,200	0.526
Subtotal indirect costs			5,617,200	9.245
Total annual manufacturing costs for 28-14-0 fertilizer			20,792,300	34.219

[a] Basis:
Remaining life of power plant – 32 years.
Coal burned – 2,625,000 tons/yr.
Power unit operating stream time – 7,000 hr/yr. Fertilizer plant on-stream time – 7,000 hr/yr.
Stack gas reheat from 118° to 250° F., indirect liquid-gas method.
Midwest plant location – 1969 costs.
Capital investment – $36,550,000 fixed; $3,358,800 working.

[b] Cost of electricity at power plant bus bar.

Table B-29. Fertilizer Company Economics - Total Venture Annual Manufacturing Costs for 26-19-0 Fertilizer Made with Ammonium Sulfate Solution and Sulfur Dioxide Obtained by Scrubbing Power Plant Stack Gas[a]—Process B

(200-mw existing power unit, 3.5% S in coal;
97,100 tons/yr fertilizer)

	Annual quantity	Unit cost, $	Total annual cost, $	$/ton of fertilizer
Direct Costs				
Delivered raw material				
Ammonia	32.1 M tons	35.00/ton	1,124,400	11.580
Phosphate rock	59.8 M tons	12.88/ton	770,800	7.938
Conditioner	1.9 M tons	46.60/ton	90,500	0.932
Antifoam	48.0 M lb	0.20/lb	9,600	0.099
Nitric acid catalyst	160 troy oz	120/troy oz	19,200	0.198
Subtotal raw material			2,014,500	20.747
Conversion costs				
Operating labor and supervision	82,300 man-hr	4.50/man-hr	370,400	3.815
Utilities				
Steam	339,700 M lb	0.60/M lb	203,800	2.099
Water	1,918,300 M gal	0.06/M gal	115,100	1.185
Electricity	28,233,300 kwh	0.006/kwh[b]	169,400	1.745
Maintenance				
Labor and material			515,000	5.304
Analyses			28,000	0.288
Subtotal conversion costs			1,401,700	14.436
Subtotal direct costs			3,416,200	35.183
Indirect Costs				
Depreciation at 10% of fixed investment			1,142,800	11.770
Local taxes and insurance at 2% of fixed investment			228,600	2.354
Overhead				
Plant, 20% of conversion costs			280,300	2.887
Administrative, research, and service, 7% of conversion costs			98,100	1.010
Subtotal indirect costs			1,749,800	18.021
Total annual manufacturing costs for 26-19-0 fertilizer			5,166,000	53.204

[a] Basis:
Remaining life of power plant—27 years.
Coal burned—554,400 tons/yr.
Power unit operating stream time—7,000 hr/yr. Fertilizer plant on-stream time—7,000 hr/yr.
Stack gas reheat from 118° to 250° F., indirect liquid-gas method.
Midwest plant location—1969 costs.
Capital investment—$11,428,000 fixed; $875,000 working.

[b] Cost of electricity at power plant bus bar.

Table B-30. Fertilizer Company Economics - Total Venture Annual Manufacturing Costs for 26-19-0 Fertilizer Made with Ammonium Sulfate Solution and Sulfur Dioxide Obtained by Scrubbing Power Plant Stack Gas[a]—Process B

(500-mw new power unit, 2.0% S in coal;
131,300 tons/yr fertilizer)

	Annual quantity	Unit cost, $	Total annual cost,$	$/ton of fertilizer
Direct Costs				
Delivered raw material				
Ammonia	43.4 M tons	35.00/ton	1,520,500	11.580
Phosphate rock	81.0 M tons	12.48/ton	1,010,900	7.699
Conditioner	2.6 M tons	46.60/ton	122,400	0.932
Antifoam	65.0 M lb	0.20/lb	13,000	0.099
Nitric acid catalyst	216 troy oz	120/troy oz	25,900	0.197
Subtotal raw material			2,692,700	20.507
Conversion costs				
Operating labor and supervision	87,700 man-hr	4.50/man-hr	394,600	3.005
Utilities				
Steam	462,770 M lb	0.40/M lb[b]	185,100	1.410
Water	2,629,620 M gal	0.05/M gal	131,500	1.002
Electricity	50,221,500 kwh	0.005/kwh[c]	251,100	1.912
Maintenance				
Labor and material			690,000	5.255
Analyses			40,000	0.304
Subtotal conversion costs			1,692,300	12.888
Subtotal direct costs			4,385,000	33.395
Indirect Costs				
Depreciation at 10% of fixed investment			1,557,400	11.861
Local taxes and insurance at 2% of fixed investment			311,500	2.372
Overhead				
Plant, 20% of conversion costs			338,500	2.578
Administrative, research, and service, 7% of conversion costs			118,500	0.902
Subtotal indirect costs			2,325,900	17.713
Total annual manufacturing costs for 26-19-0 fertilizer			6,710,900	51.111

[a] Basis:
Remaining life of power plant—35 years.
Coal burned—1,310,000 tons/yr.
Power unit operating stream time—7,000 hr/yr. Fertilizer plant on-stream time—7,000 hr/yr.
Stack gas reheat from 118° to 250° F., indirect liquid-gas method.
Midwest plant location—1969 costs.
Capital investment—$15,574,000 fixed; $1,170,800 working.

[b] Cost of steam from power plant cycle.

[c] Cost of electricity at power plant bus bar.

Table B-31. Fertilizer Company Economics - Total Venture Annual Manufacturing Costs for 26-19-0 Fertilizer Made with Ammonium Sulfate Solution and Sulfur Dioxide Obtained by Scrubbing Power Plant Stack Gas[a]—Process B

(500-mw new power unit, 3.5% S in coal;
230,000 tons/yr fertilizer)

	Annual quantity	Unit cost, $	Total annual cost, $	$/ton of fertilizer
Direct Costs				
Delivered raw material				
Ammonia	76.1 M tons	35.00/ton	2,663,500	11.580
Phosphate rock	141.8 M tons	11.88/ton	1,684,600	7.324
Conditioner	4.6 M tons	46.60/ton	214,400	0.932
Antifoam	113.4 M lb	0.18/lb	20,400	0.089
Nitric acid catalyst	377 troy oz	120/troy oz	45,200	0.197
Subtotal raw material			4,628,100	20.122
Conversion costs				
Operating labor and supervision	101,980 man-hr	4.50/man-hr	458,900	2.000
Utilities				
Steam	805,070 M lb	0.40/M lb[b]	322,000	1.400
Water	4,479,300 M gal	0.05/M gal	224,000	0.974
Electricity	61,293,750 kwh	0.005/kwh[c]	306,500	1.332
Maintenance				
Labor and material			881,000	3.830
Analyses			65,000	0.282
Subtotal conversion costs			2,257,400	9.818
Subtotal direct costs			6,885,500	29.940
Indirect Costs				
Depreciation at 10% of fixed investment			1,968,900	8.560
Local taxes and insurance at 2% of fixed investment			393,800	1.712
Overhead				
Plant, 20% of conversion costs			451,500	1.963
Administrative, research, and service 7% of conversion costs			158,000	0.687
Subtotal indirect costs			2,972,200	12.922
Total annual manufacturing costs for 26-19-0 fertilizer			9,857,700	42.862

[a] Basis:
Remaining life of power plant—35 years.
Coal burned—1,310,000 tons/yr.
Power unit operating stream time—7,000 hr/yr. Fertilizer plant on-stream time—7,000 hr/yr.
Stack gas reheat from 118° to 250° F., indirect liquid-gas method.
Midwest plant location—1969 costs.
Capital investment—$19,689,000 fixed; $1,890,500 working.

[b] Cost of steam from power plant cycle.

[c] Cost of electricity at power plant bus bar.

Table B-32. Fertilizer Company Economics - Total Venture Annual Manufacturing Costs for 26-19-0 Fertilizer Made with Ammonium Sulfate Solution and Sulfur Dioxide Obtained by Scrubbing Power Plant Stack Gas[a]—Process B

(500-mw existing power unit, 3.5% S in coal; 235,800 tons/yr fertilizer)

	Annual quantity	Unit cost, $	Total annual cost, $	$/ton of fertilizer
Direct Costs				
Delivered raw material				
Ammonia	78.0 M tons	35.00/ton	2,730,600	11.580
Phosphate rock	145.4 M tons	11.88/ton	1,727,000	7.324
Conditioner	4.7 M tons	46.60/ton	219,800	0.932
Antifoam	116.7 M lb	0.18/lb	21,000	0.089
Nitric acid catalyst	385 troy oz	120/troy oz	46,200	0.197
Subtotal raw material			4,744,600	20.122
Conversion costs				
Operating labor and supervision	102,440 man-hr	4.50/man-hr	461,000	1.955
Utilities				
Steam	825,400 M lb	0.50/M lb	412,700	1.750
Water	4,598,300 M gal	0.06/M gal	275,900	1.170
Electricity	63,660,000 kwh	0.005/kwh[b]	318,300	1.350
Maintenance				
Labor and material			902,000	3.825
Analyses			65,000	0.276
Subtotal conversion costs			2,434,900	10.326
Subtotal direct costs			7,179,500	30.448
Indirect Costs				
Depreciation at 10% of fixed investment			2,019,100	8.563
Local taxes and insurance at 2% of fixed investment			403,800	1.712
Overhead				
Plant, 20% of conversion costs			487,000	2.065
Administrative, research, and service, 7% of conversion costs			170,400	0.723
Subtotal indirect costs			3,080,300	13.063
Total annual manufacturing costs for 26-19-0 fertilizer			10,259,800	43.511

[a] Basis:
Remaining life of power plant—32 years.
Coal burned—1,339,600 tons/yr.
Power unit operating stream time—7,000 hr/yr. Fertilizer plant on-stream time—7,000 hr/yr.
Stack gas reheat from 118° to 250° F., indirect liquid-gas method.
Midwest plant location—1969 costs.
Capital investment—$20,191,000 fixed; $1,937,700 working.

[b] Cost of electricity at power plant bus bar.

Table B-33. Fertilizer Company Economics - Total Venture Annual Manufacturing Costs for 26-19-0 Fertilizer Made with Ammonium Sulfate Solution and Sulfur Dioxide Obtained by Scrubbing Power Plant Stack Gas[a]—Process B

(500-mw new power unit, 5.0% S in coal; 328,600 tons/yr fertilizer)

	Annual quantity	Unit cost, $	Total annual cost, $	$/ton of fertilizer
Direct Costs				
Delivered raw material				
Ammonia	108.7 M tons	30.00/ton	3,261,700	9.926
Phosphate rock	202.6 M tons	11.88/ton	2,406,700	7.324
Conditioner	6.6 M tons	46.60/ton	306,300	0.932
Antifoam	161.7 M lb	0.15/lb	24,300	0.074
Nitric acid catalyst	540 troy oz	120/troy oz	64,800	0.197
Subtotal raw material			6,063,800	18.453
Conversion costs				
Operating labor and supervision	117,500 man-hr	4.50/man-hr	528,700	1.609
Utilities				
Steam	1,148,000 M lb	0.40/M lb[b]	459,200	1.397
Water	6,726,720 M gal	0.04/M gal	269,100	0.819
Electricity	73,720,500 kwh	0.005/kwh[c]	368,600	1.122
Maintenance				
Labor and material			1,058,000	3.220
Analyses			90,000	0.274
Subtotal conversion costs			2,773,600	8.441
Subtotal direct costs			8,837,400	26.894
Indirect Costs				
Depreciation at 10% of fixed investment			2,352,500	7.159
Local taxes and insurance at 2% of fixed investment			470,500	1.432
Overhead				
Plant, 20% of conversion costs			554,700	1.688
Administrative, research, and service, 7% of conversion costs			194,100	0.591
Subtotal indirect costs			3,571,800	10.870
Total annual manufacturing costs for 26-19-0 fertilizer			12,409,200	37.764

[a] Basis:
Remaining life of power plant—35 years.
Coal burned—1,310,000 tons/yr.
Power unit operating stream time—7,000 hr/yr. Fertilizer plant on-stream time—7,000 hr/yr.
Stack gas reheat from 118° to 250° F., indirect liquid-gas method.
Midwest plant location—1969 costs.
Capital investment—$23,525,000 fixed; $2,393,100 working.

[b] Cost of steam from power plant cycle.

[c] Cost of electricity at power plant bus bar.

Table B-34. Fertilizer Company Economics - Total Venture Annual Manufacturing Costs for 26-19-0 Fertilizer Made with Ammonium Sulfate Solution and Sulfur Dioxide Obtained by Scrubbing Power Plant Stack Gas[a]—Process B

(1000-mw new power unit, 3.5% S in coal; 444,000 tons/yr fertilizer)

	Annual quantity	Unit cost, $	Total annual cost, $	$/ton of fertilizer
Direct Costs				
Delivered raw material				
Ammonia	146.9 M tons	30.00/ton	4,407,100	9.926
Phosphate rock	273.7 M tons	11.88/ton	3,251,900	7.324
Conditioner	8.9 M tons	46.60/ton	413,800	0.932
Antifoam	219.3 M lb	0.15/lb	32,900	0.074
Nitric acid catalyst	733 troy oz	120/troy oz	87,900	0.198
Subtotal raw material			8,193,600	18.454
Conversion costs				
Operating labor and supervision	136,700 man-hr	4.50/man-hr	615,200	1.386
Utilities				
Steam	1,678,300 M lb	0.30/M lb[b]	503,500	1.134
Water	8,680,000 M gal	0.04/M gal	347,200	0.782
Electricity	99,575,000 kwh	0.004/kwh[c]	398,300	0.897
Maintenance				
Labor and material			1,375,000	3.097
Analyses			120,000	0.270
Subtotal conversion costs			3,359,200	7.566
Subtotal direct costs			11,552,800	26.020
Indirect Costs				
Depreciation at 10% of fixed investment			3,100,000	6.982
Local taxes and insurance at 2% of fixed investment			620,000	1.397
Overhead				
Plant, 20% of conversion costs			671,800	1.513
Administrative, research, and service, 7% of conversion costs			235,100	0.530
Subtotal indirect costs			4,626,900	10.422
Total annual manufacturing costs for 26-19-0 fertilizer			16,179,700	36.442

[a] Basis:
Remaining life of power plant—35 years.
Coal burned—2,537,300 tons/yr.
Power unit operating stream time—7,000 hr/yr. Fertilizer plant on-stream time—7,000 hr/yr.
Stack gas reheat from 118° to 250° F., indirect liquid-gas method.
Midwest plant location—1969 costs.
Capital investment—$31,000,000 fixed; $3,244,200 working.

[b] Cost of steam from power plant cycle.

[c] Cost of electricity at power plant bus bar.

Table B-35. Fertilizer Company Economics - Total Venture Annual Manufacturing Costs for 26-19-0 Fertilizer Made with Ammonium Sulfate Solution and Sulfur Dioxide Obtained by Scrubbing Power Plant Stack Gas[a]—Process B

(1000-mw existing power unit, 3.5% S in coal;
460,000 tons/yr fertilizer)

	Annual quantity	Unit cost, $	Total annual cost, $	$/ton of fertilizer
Direct Costs				
Delivered raw material				
Ammonia	152.2 M tons	30.00/ton	4,566,000	9.926
Phosphate rock	283.6 M tons	11.88/ton	3,369,200	7.324
Conditioner	9.2 M tons	46.60/ton	428,700	0.932
Antifoam	226.8 M lb	0.15/lb	34,000	0.074
Nitric acid catalyst	760 troy oz	120/troy oz	91,200	0.198
Subtotal raw material			8,489,100	18.454
Conversion costs				
Operating labor and supervision	137,700 man-hr	4.50/man-hr	619,600	1.347
Utilities				
Steam	1,739,500 M lb	0.45/M lb	782,800	1.702
Water	8,988,000 M gal	0.05/M gal	449,400	0.977
Electricity	104,941,250 kwh	0.004/kwh[b]	419,800	0.912
Maintenance				
Labor and material			1,463,000	3.180
Analyses			120,000	0.261
Subtotal conversion costs			3,854,600	8.379
Subtotal direct costs			12,343,700	26.833
Indirect Costs				
Depreciation at 10% of fixed investment			3,290,400	7.153
Local taxes and insurance at 2% of fixed investment			658,100	1.431
Overhead				
Plant, 20% of conversion costs			770,900	1.676
Administrative, research, and service, 7% of conversion costs			269,800	0.586
Subtotal indirect costs			4,989,200	10.846
Total annual manufacturing costs for 26-19-0 fertilizer			17,332,900	37.679

[a] Basis:
Remaining life of power plant – 32 years.
Coal burned – 2,625,000 tons/yr.
Power unit operating stream time – 7,000 hr/yr. Fertilizer plant on-stream time – 7,000 hr/yr.
Stack gas reheat from 118° to 250° F., indirect liquid-gas method.
Midwest plant location – 1969 costs.
Capital investment – $32,904,000 fixed; $3,358,800 working.

[b] Cost of electricity at power plant bus bar.

Table B-36. Fertilizer Company Economics - Total Venture Annual Manufacturing Costs for 19-14-0 Fertilizer Made with Ammonium Sulfate Solution Obtained by Scrubbing Power Plant Stack Gas[a]—Process C

(200-mw existing power unit, 3.5% S in coal; 56,700 tons/yr fertilizer)

	Annual quantity	Unit cost, $	Total annual cost, $	$/ton of fertilizer
Direct Costs				
Delivered raw material				
Ammonia	14.4 M tons	35.00/ton	505,400	8.914
Phosphate rock	25.5 M tons	13.88/ton	343,900	6.065
Conditioner	1.1 M tons	46.60/ton	51,300	0.905
Subtotal raw material			900,600	15.884
Conversion costs				
Operating labor and supervision	69,770 man-hr	4.50/man-hr	314,000	5.538
Utilities				
Net heat from boiler	358,400 MM Btu	0.60/MM Btu[b]	215,000	3.792
Water	3,930,400 M gal	0.06/M gal	235,900	4.160
Electricity	38,776,500 kwh	0.006/kwh[b]	232,700	4.104
Maintenance				
Labor and material			417,100	7.356
Analyses			15,900	0.280
Subtotal conversion costs			1,430,600	25.230
Subtotal direct costs			2,331,200	41.114
Indirect Costs				
Depreciation at 10% fixed investment			959,000	16.914
Local taxes and insurance at 2% fixed investment			191,800	3.383
Overhead				
Plant, 20% of conversion costs			286,100	5.046
Administrative, research, and service, 7% of conversion costs			100,100	1.765
Subtotal indirect costs			1,537,000	27.108
Total annual manufacturing costs for 19-14-0 fertilizer			3,868,200	68.222

[a] Basis:
Coal burned–554,400 tons/yr.
Power unit operating stream time–7,000 hr/yr. Fertilizer plant on-stream time–7,000 hr/yr.
Stack gas reheat from 118° to 250° F., indirect liquid-gas method.
Midwest plant location–1969 costs.
Capital investment–$9,589,500 fixed; $606,000 working.

[b] Cost of electricity at power plant bus bar and heat from boiler exhaust gas at 1000° F.

Table B-37. Fertilizer Company Economics - Total Venture Annual Manufacturing Costs for 19-14-0 Fertilizer Made with Ammonium Sulfate Solution Obtained by Scrubbing Power Plant Stack Gas[a]—Process C

(500-mw new power unit, 2.0% S in coal; 76,600 tons/yr fertilizer)

	Annual quantity	Unit cost, $	Total annual cost, $	$/ton of fertilizer
Direct Costs				
Delivered raw material				
Ammonia	19.5 M tons	35.00/ton	682,400	8.909
Phosphate rock	34.4 M tons	13.88/ton	477,500	6.234
Conditioner	1.5 M tons	46.60/ton	69,900	0.913
Subtotal raw material			1,229,800	16.056
Conversion costs				
Operating labor and supervision	73,720 man-hr	4.50/man-hr	331,700	4.330
Utilities				
Net heat from boiler	484,000 MM Btu	0.40/MM Btu[b]	193,600	2.527
Water	5,503,700 M gal	0.05/M gal	275,100	3.591
Electricity	68,061,000 kwh	0.005/kwh[b]	340,300	4.443
Maintenance				
Labor and material			560,000	7.311
Analyses			19,000	0.248
Subtotal conversion costs			1,719,700	22.450
Subtotal direct costs			2,949,500	38.506
Indirect Costs				
Depreciation at 10% fixed investment			1,305,700	17.046
Local taxes and insurance at 2% fixed investment			261,100	3.409
Overhead				
Plant, 20% of conversion costs			343,900	4.489
Administrative, research, and service, 7% of conversion costs			120,400	1.572
Subtotal indirect costs			2,031,100	26.516
Total annual manufacturing costs for 19-14-0 fertilizer			4,980,600	65.022

[a] Basis:
Coal burned—1,310,000 tons/yr.
Power unit operating stream time—7,000 hr/yr. Fertilizer plant on-stream time—7,000 hr/yr.
Stack gas reheat from 118° to 250° F., indirect liquid-gas method.
Midwest plant location—1969 costs.
Capital investment—$13,057,300 fixed; $780,000 working.

[b] Cost of electricity at power plant bus bar and heat from boiler exhaust gas at 1000° F.

Table B-38. Fertilizer Company Economics - Total Venture Annual Manufacturing Costs for 19-14-0 Fertilizer Made with Ammonium Sulfate Solution Obtained by Scrubbing Power Plant Stack Gas[a]—Process C

(500-mw new power unit, 3.5% S in coal; 134,000 tons/yr fertilizer)

	Annual quantity	Unit cost, $	Total annual cost, $	$/ton of fertilizer
Direct Costs				
Delivered raw material				
Ammonia	34.2 M tons	35.00/ton	1,197,000	8.933
Phosphate rock	60.2 M tons	12.68/ton	763,300	5.696
Conditioner	2.7 M tons	46.60/ton	125,800	0.939
Subtotal raw material			2,086,100	15.568
Conversion costs				
Operating labor and supervision	82,580 man-hr	4.50/man-hr	371,600	2.773
Utilities				
Net heat from boiler	847,000 MM Btu	0.40/MM Btu[b]	338,800	2.528
Water	9,516,800 M gal	0.05/M gal	475,800	3.551
Electricity	92,481,900 kwh	0.005/kwh[b]	462,400	3.451
Maintenance				
Labor and material			706,300	5.271
Analyses			33,100	0.247
Subtotal conversion costs			2,388,000	17.821
Subtotal direct costs			4,474,100	33.389
Indirect Costs				
Depreciation at 10% fixed investment			1,635,700	12.207
Local taxes and insurance at 2% fixed investment			327,100	2.441
Overhead				
Plant, 20% of conversion costs			477,600	3.564
Administrative, research, and service, 7% of conversion costs			167,200	1.248
Subtotal indirect costs			2,607,600	19.460
Total annual manufacturing costs for 19-14-0 fertilizer			7,081,700	52.849

[a] Basis:
Coal burned–1,310,000 tons/yr.
Power unit operating stream time–7,000 hr/yr. Fertilizer plant on-stream time–7,000 hr/yr.
Stack gas reheat from 118° to 250° F., indirect liquid-gas method.
Midwest plant location–1969 costs.
Capital investment–$16,356,800 fixed; $1,185,000 working.

[b] Cost of electricity at power plant bus bar and heat from boiler exhaust gas at 1000° F.

Table B-39. Fertilizer Company Economics - Total Venture Annual Manufacturing Costs for 19-14-0 Fertilizer Made with Ammonium Sulfate Solution Obtained by Scrubbing Power Plant Stack Gas[a]—Process C

(500-mw existing power unit, 3.5% S in coal; 137,000 tons/yr fertilizer)

	Annual quantity	Unit cost, $	Total annual cost, $	$/ton of fertilizer
Direct Costs				
Delivered raw material				
Ammonia	35.0 M tons	35.00/ton	1,224,200	8.936
Phosphate rock	61.5 M tons	12.68/ton	779,800	5.692
Conditioner	2.8 M tons	46.60/ton	130,500	0.953
Subtotal raw material			2,134,500	15.581
Conversion costs				
Operating labor and supervision	83,080 man-hr	4.50/man-hr	373,900	2.729
Utilities				
Net heat from boiler	866,000 MM Btu	0.50/MM Btu[b]	433,000	3.161
Water	9,634,400 M gal	0.06/M gal	578,100	4.220
Electricity	94,056,900 kwh	0.005/kwh[b]	470,300	3.433
Maintenance				
Labor and material			748,500	5.463
Analyses			33,100	0.241
Subtotal conversion costs			2,636,900	19.247
Subtotal direct costs			4,771,400	34.828
Indirect Costs				
Depreciation at 10% fixed investment			1,733,000	12.650
Local taxes and insurance at 2% fixed investment			346,600	2.530
Overhead				
Plant, 20% of conversion costs			527,400	3.850
Administrative, research, and service, 7% of conversion costs			184,600	1.347
Subtotal indirect costs			2,791,600	20.377
Total annual manufacturing costs for 19-14-0 fertilizer			7,563,000	55.205

[a] Basis:
Coal burned–1,339,600 tons/yr.
Power unit operating stream time–7,000 hr/yr. Fertilizer plant on-stream time–7,000 hr/yr.
Stack gas reheat from 118° to 250° F., indirect liquid-gas method.
Midwest plant location–1969 costs.
Capital investment–$17,329,600 fixed; $1,260,000 working.

[b] Cost of electricity at power plant bus bar and heat from boiler exhaust gas at 1000° F.

Table B-40. Fertilizer Company Economics - Total Venture Annual Manufacturing Costs for 19-14-0 Fertilizer Made with Ammonia Sulfate Solution Obtained by Scrubbing Power Plant Stack Gas[a]—Process C

(500-mw new power unit, 5.0% S in coal; 191,400 tons/yr fertilizer)

	Annual quantity	Unit cost, $	Total annual cost, $	$/ton of fertilizer
Direct Costs				
Delivered raw material				
Ammonia	48.8 M tons	35.00/ton	1,708,000	8.924
Phosphate rock	86.0 M tons	12.48/ton	1,073,300	5.608
Conditioner	3.9 M tons	46.60/ton	181,700	0.949
Subtotal raw material			2,963,000	15.481
Conversion costs				
Operating labor and supervision	91,660 man-hr	4.50/man-hr	412,500	2.155
Utilities				
Net heat from boiler	1,210,100 MM Btu	0.40/MM Btu[b]	484,000	2.529
Water	13,552,600 M gal	0.04/M gal	542,100	2.832
Electricity	121,410,800 kwh	0.005/kwh[b]	607,000	3.171
Maintenance				
Labor and material			811,900	4.242
Analyses			39,700	0.207
Subtotal conversion costs			2,897,200	15.136
Subtotal direct costs			5,860,200	30.617
Indirect Costs				
Depreciation at 10% fixed investment			1,932,100	10.095
Local taxes and insurance at 2% fixed investment			386,400	2.019
Overhead				
Plant, 20% of conversion costs			579,400	3.027
Administrative, research, and service, 7% of conversion costs			202,800	1.060
Subtotal indirect costs			3,100,700	16.201
Total annual manufacturing costs for 19-14-0 fertilizer			8,960,900	46.818

[a] Basis:
Coal burned–1,310,000 tons/yr.
Power unit operating stream time–7,000 hr/yr. Fertilizer plant on-stream time–7,000 hr/yr.
Stack gas reheat from 118° to 250° F., indirect liquid-gas method.
Midwest plant location–1969 costs.
Capital investment–$19,321,300 fixed; $1,515,000 working.

[b] Cost of electricity at power plant bus bar and heat from boiler exhaust gas at 1000° F.

Table B-41. Fertilizer Company Economics - Total Venture Annual Manufacturing Costs for 19-14-0 Fertilizer Made with Ammonium Sulfate Solution Obtained by Scrubbing Power Plant Stack Gas[a]—Process C

(1000-mw new power unit, 3.5% S in coal;
259,500 tons/yr fertilizer)

	Annual quantity	Unit cost, $	Total annual cost, $	$/ton of fertilizer
Direct Costs				
Delivered raw material				
Ammonia	66.2 M tons	35.00/ton	2,318,000	8.933
Phosphate rock	116.6 M tons	12.28/ton	1,431,800	5.518
Conditioner	5.2 M tons	46.60/ton	242,300	0.934
Subtotal raw material			3,992,100	15.385
Conversion costs				
Operating labor and supervision	101,820 man-hr	4.50/man-hr	458,200	1.766
Utilities				
Net heat from boiler	1,694,000 MM Btu	0.30/MM Btu[b]	508,200	1.958
Water	19,033,600 M gal	0.04/M gal	761,300	2.934
Electricity	181,254,500 kwh	0.004/kwh[b]	988,200	3.808
Maintenance				
Labor and material			1,062,200	4.093
Analyses			53,000	0.204
Subtotal conversion costs			3,831,100	14.763
Subtotal direct costs			7,823,200	30.148
Indirect Costs				
Depreciation at 10% fixed investment			2,463,900	9.495
Local taxes and insurance at 2% fixed investment			492,800	1.900
Overhead				
Plant, 20% of conversion costs			766,200	2.952
Administrative, research, and service, 7% of conversion costs			268,200	1.033
Subtotal indirect costs			3,991,100	15.380
Total annual manufacturing costs for 19-14-0 fertilizer			11,814,300	45.528

[a] Basis:
Coal burned—2,537,300 tons/yr.
Power unit operating stream time—7,000 hr/yr. Fertilizer plant on-stream time—7,000 hr/yr.
Stack gas reheat from 118° to 250° F., indirect liquid-gas method.
Midwest plant location—1969 costs.
Capital investment—$24,639,300 fixed; $2,010,000 working.

[b] Cost of electricity at power plant bus bar and heat from boiler exhaust gas at 1000° F.

Table B-42. Fertilizer Company Economics - Total Venture Annual Manufacturing Costs for 19-14-0 Fertilizer Made with Ammonium Sulfate Solution Obtained by Scrubbing Power Plant Stack Gas[a]—Process C

(1000-mw existing power unit, 3.5% S in coal; 268,000 tons/yr fertilizer)

	Annual quantity	Unit cost, $	Total annual cost, $	$/ton of fertilizer
Direct Costs				
Delivered raw material				
Ammonia	68.4 M tons	35.00/ton	2,394,000	8.933
Phosphate rock	120.4 M tons	12.08/ton	1,454,400	5.427
Conditioner	5.4 M tons	46.60/ton	251,600	0.939
Subtotal raw material			4,100,000	15.299
Conversion costs				
Operating labor and supervision	102,820 man-hr	4.50/man-hr	462,700	1.726
Utilities				
Net heat from boiler	1,642,000 MM Btu	0.45/MM Btu[b]	738,900	2.757
Water	18,722,800 M gal	0.05/M gal	936,100	3.493
Electricity	181,776,000 kwh	0.004/kwh[b]	727,100	2.713
Maintenance				
Labor and material			1,149,500	4.289
Analyses			52,900	0.197
Subtotal conversion costs			4,067,200	15.175
Subtotal direct costs			8,167,200	30.474
Indirect Costs				
Depreciation at 10% fixed investment			2,664,600	9.943
Local taxes and insurance at 2% fixed investment			532,900	1.988
Overhead				
Plant, 20% of conversion costs			813,400	3.035
Administrative, research, and service, 7% of conversion costs			284,700	1.063
Subtotal indirect costs			4,295,600	16.029
Total annual manufacturing costs for 19-14-0 fertilizer			12,462,800	46.503

[a] Basis:
Coal burned–2,625,000 tons/yr.
Power unit operating stream time–7,000 hr/yr. Fertilizer plant on-stream time–7,000 hr/yr.
Stack gas reheat from 118° to 250° F., indirect liquid-gas method.
Midwest plant location–1969 costs.
Capital investment–$26,646,400 fixed; $2,175,000 working.

[b] Cost of electricity at power plant bus bar and heat from boiler exhaust gas at 1000° F.

Table B-43. Economics for Power - Fertilizer Company Cooperative Venture Average Annual Operating Costs for Scrubbing Power Plant Stack Gas to Produce Ammonium Sulfate Solution[a]—Process A

(200-mw existing power unit, 3.5% S in coal;
65,860 tons ammonium sulfate/yr)

	Annual quantity	Unit cost, $	Total annual cost, $	Cost/ton of coal burned, $
Direct Costs				
Delivered raw material				
Ammonia	17.4 M tons	35.00/ton	610,400	1.101
Conversion costs				
Operating labor and supervision	10,760 man-hr	4.50/man-hr	48,400	0.087
Utilities				
Water	886,700 M gal	0.06/M gal	53,200	0.096
Electricity	22,183,000 kwh	0.006/kwh[b]	133,100	0.240
Maintenance				
Labor and material			115,200	0.208
Analyses			12,000	0.022
Subtotal conversion costs			361,900	0.653
Subtotal direct costs			972,300	1.754
Indirect Costs				
Average capital charges at 15.1% of fixed investment			434,900	0.784
Overhead				
Plant, 20% of conversion costs			72,400	0.130
Administrative, 10% of operating labor			4,800	0.009
Subtotal indirect costs			512,100	0.923

	Cost/ton of ammonium sulfate, $	Total annual cost, $	Cost/ton of coal burned, $
Total annual operating costs for ammonium sulfate solution	22.539	1,484,400	2.677
Cost of air pollution control by alternate wet scrubbing - limestone process	12.396	816,400	1.473
Minimum expected transfer price of ammonium sulfate solution to fertilizer plant	10.143	668,000	1.204

[a] Basis:
Remaining life of power plant - 27 years.
Coal burned - 554,400 tons/yr - 0.792 lb/kwh.
Power unit operating stream time - 7,000 hr/yr.
Midwest plant location - 1969 costs.
Capital investment - $2,880,000 fixed; $34,000 working.

[b] Cost of electricity at power plant bus bar.

Table B-44. Economics for Power - Fertilizer Company Cooperative Venture Annual Manufacturing Costs for 28-14-0 Fertilizer Made with Ammonium Sulfate Solution Obtained by Scrubbing Power Plant Stack Gas[a]—Process A

(200-mw existing power unit, 3.5% S in coal; 128,600 tons/yr fertilizer)

	Annual quantity	Unit cost, $	Total annual cost, $	$/ton of fertilizer
Direct Costs				
Delivered raw material				
Ammonia	28.1 M tons	35.00/ton	981,800	7.635
Phosphate rock	60.9 M tons	12.88/ton	784,400	6.100
Ammonium sulfate (solution at minimum transfer price)	65.9 M tons	10.14/ton	668,000	5.194
Conditioner	2.5 M tons	46.60/ton	117,900	0.917
Antifoam	48.8 M lb	0.20/lb	9,800	0.076
Nitric acid catalyst	241 troy oz	120/troy oz	28,900	0.225
Subtotal raw material			2,590,800	20.147
Conversion costs				
Operating labor and supervision	59,240 man-hr	4.50/man-hr	266,600	2.073
Utilities				
Steam	471,200 M lb	0.60/M lb[b]	282,700	2.198
Water	2,272,900 M gal	0.06/M gal	136,400	1.061
Electricity	14,434,000 kwh	0.006/kwh[b]	86,600	0.673
Maintenance				
Labor and material			449,200	3.493
Analyses			24,000	0.187
Subtotal conversion costs			1,245,500	9.685
Subtotal direct costs			3,836,300	29.832
Indirect Costs				
Depreciation at 10% of fixed investment			964,000	7.496
Local taxes and insurance at 2% of fixed investment			192,800	1.499
Overhead				
Plant, 20% of conversion costs			249,100	1.937
Administrative, research, and service, 10% of conversion costs			124,600	0.969
Subtotal indirect costs			1,530,500	11.901
Total annual manufacturing costs for 28-14-0 fertilizer			5,366,800	41.733

[a] Basis:
Fertilizer plant on-stream time—7,000 hr/yr.
Midwest plant location—1969 costs.
Fertilizer capital investment—$9,640,000 fixed; $841,000 working.

[b] Cost of power and steam from power plant.

Table B-45. Economics for Power - Fertilizer Company Cooperative Venture Average Annual Operating Costs for Scrubbing Power Plant Stack Gas to Produce Ammonium Sulfate Solution[a]—Process A

(500-mw new power unit, 2.0% S in coal;
89,000 tons ammonium sulfate/yr)

	Annual quantity	Unit cost, $	Total annual cost, $	Cost/ton of coal burned, $
Direct Costs				
Delivered raw material				
Ammonia	23.8 M tons	35.00/ton	833,000	0.636
Conversion costs				
Operating labor and supervision	13,430 man-hr	4.50/man-hr	60,400	0.046
Utilities				
Water	1,245,000 M gal	0.05/M gal	62,300	0.048
Electricity	43,260,000 kwh	0.005/kwh[b]	216,300	0.165
Maintenance				
Labor and material			219,400	0.167
Analyses			15,000	0.011
Subtotal conversion costs			573,400	0.437
Subtotal direct costs			1,406,400	1.073
Indirect Costs				
Average capital charges at 14.5% of fixed investment			795,300	0.607
Overhead				
Plant, 20% of conversion costs			114,700	0.088
Administrative, 10% of operating labor			6,000	0.004
Subtotal indirect costs			916,000	0.699

	Cost/ton of ammonium sulfate, $	Total annual cost, $	Cost/ton of coal burned, $
Total annual operating costs for ammonium sulfate solution	26.094	2,322,400	1.772
Cost of air pollution control by alternate wet scrubbing - limestone process	14.846	1,321,300	1.008
Minimum expected transfer price of ammonium sulfate solution to fertilizer plant	11.248	1,001,100	0.764

[a] Basis:
Remaining life of power plant – 35 years.
Coal burned – 1,310,000 tons/yr – 0.75 lb/kwh.
Power unit operating stream time – 7,000 hr/yr.
Midwest plant location – 1969 costs.
Capital investment – $5,485,000 fixed; $54,400 working.

[b] Cost of electricity at power plant bus bar.

Table B-46. Economics for Power - Fertilizer Company Cooperative Venture Annual Manufacturing Costs for 28-14-0 Fertilizer Made with Ammonium Sulfate Solution Obtained by Scrubbing Power Plant Stack Gas[a]—Process A

(500-mw new power unit, 2.0% S in coal;
173,600 tons/yr fertilizer)

	Annual quantity	Unit cost, $	Total annual cost, $	$/ton of fertilizer
Direct Costs				
Delivered raw material				
Ammonia	26.4 M tons	35.00/ton	1,315,000	7.575
Phosphate rock	82.2 M tons	12.48/ton	1,025,900	5.910
Ammonium sulfate (solution at minimum transfer price)	89.0 M tons	11.25/ton	1,001,100	5.767
Conditioner	3.4 M tons	46.60/ton	159,700	0.920
Antifoam	65.8 M lb	0.20/lb	13,600	0.076
Nitric acid catalyst	325 troy oz	120/troy oz	39,000	0.225
Subtotal raw material			3,554,300	20.473
Conversion costs				
Operating labor and supervision	62,570 man-hr	4.50/man-hr	281,600	1.622
Utilities				
Steam	640,290 M lb	0.40/M lb[b]	256,100	1.475
Water	3,034,000 M gal	0.05/M gal	151,700	0.874
Electricity	19,887,000 kwh	0.005/kwh[b]	99,400	0.573
Maintenance				
Labor and material			531,600	3.062
Analyses			28,000	0.161
Subtotal conversion costs			1,348,400	7.767
Subtotal direct costs			4,902,700	28.240
Indirect Costs				
Depreciation at 10% of fixed investment			1,121,000	6.457
Local taxes and insurance at 2% of fixed investment			224,200	1.291
Overhead				
Plant, 20% of conversion costs			269,700	1.554
Administrative, research, and service, 10% of conversion costs			134,800	0.777
Subtotal indirect costs			1,749,700	10.079
Total annual manufacturing costs for 28-14-0 fertilizer			6,652,400	38.319

[a] Basis:
Fertilizer plant on-stream time–7,000 hr/yr.
Midwest plant location–1969 costs.
Fertilizer capital investment–$11,210,000 fixed; $1,116,400 working.

[b] Cost of power and steam from power plant.

Table B-47. Economics for Power - Fertilizer Company Cooperative Venture Average Annual Operating Costs for Scrubbing Power Plant Stack Gas to Produce Ammonium Sulfate Solution[a]—Process A

(500-mw new power unit, 3.5% S in coal; 155,925 tons ammonium sulfate/yr)

	Annual quantity	Unit cost, $	Total annual cost, $	Cost/ton of coal burned, $
Direct Costs				
Delivered raw material				
Ammonia	41.3 M tons	35.00/ton	1,445,500	1.103
Conversion costs				
Operating labor and supervision	13,340 man-hr	4.50/man-hr	60,000	0.046
Utilities				
Water	2,137,000 M gal	0.05/M gal	106,800	0.081
Electricity	49,322,000 kwh	0.005/kwh[b]	246,600	0.188
Maintenance				
Labor and material			235,600	0.180
Analyses			25,000	0.019
Subtotal conversion costs			674,000	0.514
Subtotal direct costs			2,119,500	1.617
Indirect Costs				
Average capital charges at 14.5% of fixed investment			854,100	0.652
Overhead				
Plant, 20% of conversion costs			134,800	0.103
Administrative, 10% of operating labor			6,000	0.004
Subtotal indirect costs			994,900	0.759

	Cost/ton of ammonium sulfate, $	Total annual cost, $	Cost/ton of coal burned, $
Total annual operating costs for ammonium sulfate solution	19.974	3,114,400	2.376
Cost of air pollution control by alternate wet scrubbing - limestone process	10.365	1,616,100	1.233
Minimum expected transfer price of ammonium sulfate solution to fertilizer plant	9.609	1,498,300	1.143

[a] Basis:
Remaining life of power plant—35 years.
Coal burned—1,310,000 tons/yr—0.75 lb/kwh.
Power unit operating stream time—7,000 hr/yr.
Midwest plant location—1969 costs.
Capital investment—$5,890,000 fixed; $85,000 working.

[b] Cost of electricity at power plant bus bar.

Table B-48. Economics for Power - Fertilizer Company Cooperative Venture Annual Manufacturing Costs for 28-14-0 Fertilizer Made with Ammonium Sulfate Solution Obtained by Scrubbing Power Plant Stack Gas[a]—Process A

(500-mw new power unit, 3.5% S in coal:
303,800 tons/yr fertilizer)

	Annual quantity	Unit cost, $	Total annual cost, $	$/ton of fertilizer
Direct Costs				
Delivered raw material				
Ammonia	66.2 M tons	35.00/ton	2,317,000	7.627
Phosphate rock	143.9 M tons	11.88/ton	1,709,500	5.627
Ammonium sulfate (solution at minimum transfer price)	155.9 M tons	9.609/ton	1,498,300	4.932
Conditioner	6.0 M tons	46.60/ton	279,600	0.920
Antifoam	115.2 M lb	0.18/lb	20,700	0.068
Nitric acid catalyst	570 troy oz	120/troy oz	68,400	0.225
Subtotal raw material			5,893,500	19.399
Conversion costs				
Operating labor and supervision	84,660 man-hr	4.50/man-hr	381,000	1.254
Utilities				
Steam	1,112,000 M lb	0.40/M lb[b]	448,100	1.475
Water	5,213,000 M gal	0.05/M gal	260,700	0.858
Electricity	33,033,000 kwh	0.005/kwh[b]	165,200	0.544
Maintenance				
Labor and material			730,400	2.404
Analyses			50,000	0.165
Subtotal conversion costs			2,035,400	6.700
Subtotal direct costs			7,928,900	26.099
Indirect Costs				
Depreciation at 10% of fixed investment			1,558,000	5.128
Local taxes and insurance at 2% of fixed investment			311,600	1.026
Overhead				
Plant, 20% of conversion costs			407,100	1.340
Administrative, research, and service, 10% of conversion costs			203,500	0.670
Subtotal indirect costs			2,480,200	8.164
Total annual manufacturing costs for 28-14-0 fertilizer			10,409,100	34.263

[a] Basis:
Fertilizer plant on-stream time–7,000 hr/yr.
Midwest plant location–1969 costs.
Fertilizer capital investment–$15,580,000 fixed; $1,805,500 working.

[b] Cost of power and steam from power plant.

Table B-49. Economics for Power - Fertilizer Company Cooperative Venture Average Annual Operating Costs for Scrubbing Power Plant Stack Gas to Produce Ammonium Sulfate Solution[a]—Process A

(500-mw existing power unit, 3.5% S in coal;
159,500 tons ammonium sulfate/yr)

	Annual quantity	Unit cost, $	Total annual cost, $	Cost/ton of coal burned, $
Direct Costs				
Delivered raw material				
Ammonia	42.2 M tons	35.00/ton	1,477,600	1.103
Conversion costs				
Operating labor and supervision	13,700 man-hr	4.50/man-hr	61,600	0.046
Utilities				
Water	2,188,000 M gal	0.06/M gal	131,300	0.098
Electricity	51,440,000 kwh	0.005/kwh[b]	257,200	0.192
Maintenance				
Labor and material			250,000	0.187
Analyses			25,000	0.018
Subtotal conversion costs			725,100	0.541
Subtotal direct costs			2,202,700	1.644
Indirect Costs				
Average capital charges at 14.8% of fixed investment			922,000	0.688
Overhead				
Plant, 20% of conversion costs			145,000	0.108
Administrative, 10% of operating labor			6,200	0.005
Subtotal indirect costs			1,073,200	0.801

	Cost/ton of ammonium sulfate, $	Total annual cost, $	Cost/ton of coal burned, $
Total annual operating costs for ammonium sulfate solution	20.539	3,275,900	2.445
Cost of air pollution control by alternate wet scrubbing - limestone process	10.641	1,697,300	1.267
Minimum expected transfer price of ammonium sulfate solution to fertilizer plant	9.898	1,578,600	1.178

[a] Basis:
Remaining life of power plant—32 years.
Coal burned—1,339,600 tons/yr—0.767 lb/kwh.
Power unit operating stream time—7,000 hr/yr.
Midwest plant location—1969 costs.
Capital investment—$6,230,000 fixed; $85,000 working.

[b] Cost of electricity at power plant bus bar.

Table B-50. Economics for Power - Fertilizer Company Cooperative Venture Annual Manufacturing Costs for 28-14-0 Fertilizer Made with Ammonium Sulfate Solution Obtained by Scrubbing Power Plant Stack Gas[a]—Process A

(500-mw existing power unit, 3.5% S in coal; 310,800 tons/yr fertilizer)

	Annual quantity	Unit cost, $	Total annual cost, $	$/ton of fertilizer
Direct Costs				
Delivered raw material				
Ammonia	67.8 M tons	35.00/ton	2,372,400	7.633
Phosphate rock	147.2 M tons	11.88/ton	1,748,700	5.627
Ammonium sulfate (solution at minimum transfer price)	159.5 M tons	9.898/ton	1,578,600	5.079
Conditioner	6.1 M tons	46.60/ton	284,300	0.915
Antifoam	117.8 M lb	0.18/lb	21,200	0.068
Nitric acid catalyst	583 troy oz	120/troy oz	70,000	0.225
Subtotal raw material			6,075,200	19.547
Conversion costs				
Operating labor and supervision	84,800 man-hr	4.50/man-hr	381,700	1.228
Utilities				
Steam	1,137,600 M lb	0.50/M lb[b]	568,800	1.830
Water	5,331,000 M gal	0.06/M gal	319,800	1.029
Electricity	31,965,000 kwh	0.005/kwh[b]	159,800	0.514
Maintenance				
Labor and material			750,000	2.413
Analyses			50,000	0.161
Subtotal conversion costs			2,230,100	7.175
Subtotal direct costs			8,305,300	26.722
Indirect Costs				
Depreciation at 10% of fixed investment			1,609,000	5.177
Local taxes and insurance at 2% of fixed investment			321,800	1.035
Overhead				
Plant, 20% of conversion costs			446,000	1.435
Administrative, research, and service, 10% of conversion costs			223,000	0.718
Subtotal indirect costs			2,599,800	8.365
Total annual manufacturing costs for 28-14-0 fertilizer			10,905,100	35.087

[a] Basis:
Fertilizer plant on-stream time—7,000 hr/yr.
Midwest plant location—1969 costs.
Fertilizer capital investment—$16,090,000 fixed; $1,852,700 working.

[b] Cost of power and steam from power plant.

Table B-51. Economics for Power - Fertilizer Company Cooperative Venture Average Annual Operating Costs for Scrubbing Power Plant Stack Gas to Produce Ammonium Sulfate Solution[a]—Process A

(500-mw new power unit, 5.0% S in coal;
222,810 tons ammonium sulfate/yr)

	Annual quantity	Unit cost, $	Total annual cost, $	Cost/ton of coal burned, $
Direct Costs				
Delivered raw material				
Ammonia	59.0 M tons	30.00/ton	1,770,000	1.351
Conversion costs				
Operating labor and supervision	13,400 man-hr	4.50/man-hr	60,300	0.046
Utilities				
Water	3,028,000 M gal	0.04/M gal	121,100	0.092
Electricity	56,000,000 kwh	0.005/kwh[b]	280,000	0.214
Maintenance				
Labor and material			250,000	0.191
Analyses			30,000	0.023
Subtotal conversion costs			741,400	0.566
Subtotal direct costs			2,511,400	1.917
Indirect Costs				
Average capital charges at 14.5% of fixed investment			907,700	0.693
Overhead				
Plant, 20% of conversion costs			148,300	0.113
Administrative, 10% of operating labor			6,000	0.005
Subtotal indirect costs			1,062,000	0.811
		Cost/ton of ammonium sulfate, $	Total annual cost, $	Cost/ton of coal burned, $
Total annual operating costs for ammonium sulfate solution		16.038	3,573,400	2.728
Cost of air pollution control by alternate wet scrubbing - limestone process		8.612	1,918,900	1.465
Minimum expected transfer price of ammonium sulfate solution to fertilizer plant		7.426	1,654,500	1.263

[a] Basis:
Remaining life of power plant – 35 years.
Coal burned – 1,310,000 tons/yr – 0.75 lb/kwh.
Power unit operating stream time – 7,000 hr/yr.
Midwest plant location – 1969 costs.
Capital investment – $6,260,000 fixed; $104,100 working.

[b] Cost of electricity at power plant bus bar.

Table B-52. Economics for Power - Fertilizer Company Cooperative Venture Annual Manufacturing Costs for 28-14-0 Fertilizer Made with Ammonium Sulfate Solution Obtained by Scrubbing Power Plant Stack Gas[a]—Process A

(500-mw new power unit, 5.0% S in coal;
434,000 tons/yr fertilizer)

	Annual quantity	Unit cost, $	Total annual cost, $	$/ton of fertilizer
Direct Costs				
Delivered raw material				
Ammonia	94.9 M tons	30.00/ton	2,848,000	6.562
Phosphate rock	205.6 M tons	11.88/ton	2,442,100	5.627
Ammonium sulfate (solution at minimum transfer price)	222.81 M tons	7.426/ton	1,654,500	3.812
Conditioner	8.6 M tons	46.60/ton	399,300	0.920
Antifoam	164.2 M lb	0.15/lb	24,600	0.057
Nitric acid catalyst	815 troy oz	120/troy oz	97,800	0.225
Subtotal raw material			7,466,300	17.203
Conversion costs				
Operating labor and supervision	104,600 man-hr	4.50/man-hr	470,700	1.085
Utilities				
Steam	1,670,000 M lb	0.40/M lb[b]	668,000	1.539
Water	6,915,000 M gal	0.04/M gal	276,600	0.637
Electricity	27,475,000 kwh	0.005/kwh[b]	137,400	0.318
Maintenance				
Labor and material			875,000	2.016
Analyses			60,000	0.138
Subtotal conversion costs			2,487,700	5.732
Subtotal direct costs			9,954,000	22.935
Indirect Costs				
Depreciation at 10% of fixed investment			1,987,000	4.578
Local taxes and insurance at 2% of fixed investment			397,400	0.916
Overhead				
Plant, 20% of conversion costs			497,500	1.146
Administrative, research, and service, 10% of conversion costs			248,800	0.573
Subtotal indirect costs			3,130,700	7.213
Total annual manufacturing costs for 28-14-0 fertilizer			13,084,700	30.148

[a] Basis:
Fertilizer plant on-stream time–7,000 hr/yr.
Midwest plant location–1969 costs.
Fertilizer capital investment–$19,870,000 fixed; $2,289,000 working.

[b] Cost of power and steam from power plant.

Table B-53. Economics for Power - Fertilizer Company Cooperative Venture Average Annual Operating Costs for Scrubbing Power Plant Stack Gas to Produce Ammonium Sulfate Solution[a]—Process A

(1000-mw new power unit, 3.5% S in coal; 301,560 tons ammonium sulfate/yr)

	Annual quantity	Unit cost, $	Total annual cost, $	Cost/ton of coal burned, $
Direct Costs				
Delivered raw material				
Ammonia	79.8 M tons	30.00/ton	2,395,200	0.944
Conversion costs				
Operating labor and supervision	15,200 man-hr	4.50/man-hr	68,500	0.027
Utilities				
Water	4,123,000 M gal	0.04/M gal	164,900	0.065
Electricity	93,250,000 kwh	0.004/kwh[b]	373,000	0.147
Maintenance				
Labor and material			370,000	0.146
Analyses			40,000	0.016
Subtotal conversion costs			1,016,400	0.401
Subtotal direct costs			3,411,600	1.345
Indirect Costs				
Average capital charges at 14.5% of fixed investment			1,342,700	0.529
Overhead				
Plant, 20% of conversion costs			203,300	0.080
Administrative, 10% of operating labor			6,900	0.003
Subtotal indirect costs			1,552,900	0.612

	Cost/ton of ammonium sulfate, $	Total annual cost, $	Cost/ton of coal burned, $
Total annual operating costs for ammonium sulfate solution	16.463	4,964,500	1.957
Cost of air pollution control by alternate wet scrubbing - limestone process	8.522	2,569,900	1.013
Minimum expected transfer price of ammonium sulfate solution to fertilizer plant	7.941	2,394,600	0.944

[a] Basis:
Remaining life of power plant – 35 years.
Coal burned – 2,537,300 tons/yr – 0.725 lb/kwh.
Power unit operating stream time – 7,000 hr/yr.
Midwest plant location – 1969 costs.
Capital investment – $9,260,000 fixed; $145,800 working.

[b] Cost of electricity at power plant bus bar.

Table B-54. Economics for Power - Fertilizer Company Cooperative Venture Annual Manufacturing Costs for 28-14-0 Fertilizer Made with Ammonium Sulfate Solution Obtained by Scrubbing Power Plant Stack Gas[a]—Process A

(1000-mw new power unit, 3.5% S in coal;
587,500 tons/yr fertilizer)

	Annual quantity	Unit cost, $	Total annual cost, $	$/ton of fertilizer
Direct Costs				
Delivered raw material				
Ammonia	128.6 M tons	30.00/ton	3,856,800	6.565
Phosphate rock	278.3 M tons	11.88/ton	3,306,200	5.627
Ammonium sulfate (solution at minimum transfer price)	301.6 M tons	7.941/ton	2,394,600	4.076
Conditioner	11.5 M tons	46.60/ton	537,300	0.917
Antifoam	223.4 M lb	0.15/lb	33,500	0.057
Nitric acid catalyst	111.2 troy oz	120/troy oz	133,400	0.225
Subtotal raw material			10,261,800	17.467
Conversion costs				
Operating labor and supervision	119,800 man-hr	4.50/man-hr	539,000	0.917
Utilities				
Steam	2,276,000 M lb	0.30/M lb[b]	682,800	1.162
Water	8,014,000 M gal	0.04/M gal	320,600	0.546
Electricity	39,989,000 kwh	0.004/kwh[b]	160,000	0.272
Maintenance				
Labor and material			1,180,000	2.009
Analyses			80,000	0.136
Subtotal conversion costs			2,962,400	5.042
Subtotal direct costs			13,224,200	22.509
Indirect Costs				
Depreciation at 10% of fixed investment			2,524,000	4.296
Local taxes and insurance at 2% of fixed investment			504,800	0.859
Overhead				
Plant, 20% of conversion costs			592,500	1.009
Administrative, research, and service, 10% of conversion costs			296,200	0.504
Subtotal indirect costs			3,917,500	6.668
Total annual manufacturing costs for 28-14-0 fertilizer			17,141,700	29.177

[a] Basis:
Fertilizer plant on-stream time–7,000 hr/yr.
Midwest plant location–1969 costs.
Fertilizer capital investment–$25,240,000 fixed; $3,098,400 working.

[b] Cost of power and steam from power plant.

Table B-55. Economics for Power - Fertilizer Company Cooperative Venture Average Annual Operating Costs for Scrubbing Power Plant Stack Gas to Produce Ammonium Sulfate Solution[a]—Process A

(1000-mw existing power unit, 3.5% S in coal; 311,850 tons ammonium sulfate/yr)

	Annual quantity	Unit cost, $	Total annual cost, $	Cost/ton of coal burned, $
Direct Costs				
Delivered raw material				
Ammonia	82.6 M tons	30.00/ton	2,478,000	0.944
Conversion costs				
Operating labor and supervision	16,000 man-hr	4.50/man-hr	74,700	0.028
Utilities				
Water	4,273,000 M gal	0.05/M gal	213,700	0.082
Electricity	98,434,000 kwh	0.004/kwh[b]	393,700	0.150
Maintenance				
Labor and material			455,000	0.173
Analyses			40,000	0.015
Subtotal conversion costs			1,177,100	0.448
Subtotal direct costs			3,655,100	1.392
Indirect Costs				
Average capital charges at 14.8% of fixed investment			1,463,700	0.558
Overhead				
Plant, 20% of conversion costs			235,400	0.090
Administrative, 10% of operating labor			7,500	0.002
Subtotal indirect costs			1,706,600	0.650

	Cost/ton of ammonium sulfate, $	Total annual cost, $	Cost/ton of coal burned, $
Total annual operating costs for ammonium sulfate solution	17.193	5,361,700	2.042
Cost of air pollution control by alternate wet scrubbing - limestone process	8.765	2,733,400	1.041
Minimum expected transfer price of ammonium sulfate solution to fertilizer plant	8.428	2,628,300	1.001

[a] Basis:
Remaining life of power plant–32 years.
Coal burned–2,625,000 tons/yr–0.75 lb/kwh.
Power unit operating stream time–7,000 hr/yr.
Midwest plant location–1969 costs.
Capital investment–$9,890,000 fixed; $145,800 working.

[b] Cost of electricity at power plant bus bar.

Table B-56. Economics for Power - Fertilizer Company Cooperative Venture Annual Manufacturing Costs for 28-14-0 Fertilizer Made with Ammonium Sulfate Solution Obtained by Scrubbing Power Plant Stack Gas[a]—Process A

(1000-mw existing power unit, 3.5% S in coal; 607,600 tons/yr fertilizer)

	Annual quantity	Unit cost, $	Total annual cost, $	$/ton of fertilizer
Direct Costs				
Delivered raw material				
Ammonia	132.9 M tons	30.00/ton	3,987,000	6.562
Phosphate rock	287.8 M tons	11.88/ton	3,419,000	5.627
Ammonium sulfate (solution at minimum transfer price)	311.85 M tons	8.428/ton	2,628,300	4.326
Conditioner	12.0 M tons	46.60/ton	559,200	0.920
Antifoam	231.0 M lb	0.15/lb	34,700	0.057
Nitric acid catalyst	115.0 troy oz	120/troy oz	137,000	0.225
Subtotal raw material			10,765,200	17.717
Conversion costs				
Operating labor and supervision	119,400 man-hr	4.50/man-hr	537,300	0.884
Utilities				
Steam	2,354,000 M lb	0.45/M lb[b]	1,059,300	1.743
Water	8,278,000 M gal	0.05/M gal	413,900	0.681
Electricity	36,905,000 kwh	0.004/kwh[b]	147,600	0.243
Maintenance				
Labor and material			1,145,000	1.884
Analyses			80,000	0.132
Subtotal conversion costs			3,383,100	5.567
Subtotal direct costs			14,148,300	23.284
Indirect Costs				
Depreciation at 10% of fixed investment			2,666,000	4.387
Local taxes and insurance at 2% of fixed investment			533,200	0.878
Overhead				
Plant, 20% of conversion costs			676,600	1.114
Administrative, research, and service, 10% of conversion costs			33,800	0.057
Subtotal indirect costs			3,909,600	6.436
Total annual manufacturing costs for 28-14-0 fertilizer			18,057,900	29.720

[a] Basis:
Fertilizer plant on-stream time–7,000 hr/yr.
Midwest plant location–1969 costs.
Fertilizer capital investment–$26,660,000 fixed; $3,213,000 working.

[b] Cost of power and steam from power plant.

Table B-57. Economics for Power - Fertilizer Company Cooperative Venture Average Annual Operating Costs for Scrubbing Power Plant Stack Gas to Produce Ammonium Sulfate Solution and Sulfur Dioxide[a]—Process B

(200-mw existing power unit, 3.5% S in coal;
43,530 tons ammonium sulfate/yr;
30,340 tons sulfur dioxide/yr)

	Annual quantity	Unit cost, $	Total annual cost, $	Cost/ton of coal burned, $
Direct Costs				
Delivered raw material				
Ammonia	11.5 M tons	35.00/ton	403,000	0.727
Conversion costs				
Operating labor and supervision	11,400 man-hr	4.50/man-hr	51,300	0.093
Utilities				
Water	153,500 M gal	0.06/M gal	9,200	0.017
Electricity	14,883,300 kwh	0.006/kwh[b]	89,300	0.161
Maintenance				
Labor and material			105,400	0.190
Analyses			7,000	0.012
Subtotal conversion costs			262,200	0.473
Subtotal direct costs			665,200	1.200
Indirect Costs				
Average capital charges at 15.1% of fixed investment			397,700	0.717
Overhead				
Plant, 20% of conversion costs			52,400	0.095
Administrative, 10% of operating labor			5,100	0.009
Subtotal indirect costs			455,200	0.821

	Cost/ton of ammonium sulfate and sulfur dioxide, $	Total annual cost, $	Cost/ton of coal burned, $
Total annual operating costs for ammonium sulfate solution and sulfur dioxide	15.167	1,120,400	2.021
Cost of air pollution control by alternate wet scrubbing - limestone process	11.052	816,400	1.473
Minimum expected transfer price of ammonium sulfate solution and sulfur dioxide to fertilizer plant	4.115	304,000	0.548

[a] Basis:
Remaining life of power plant–27 years.
Coal burned–554,400 tons/yr–0.792 lb/kwh.
Stack gas reheat from 118° to 250° F., indirect liquid-gas method.
Power unit on-stream time–7,000 hr.
Midwest plant location–1969 costs.
Capital investment–$2,634,000 fixed; $34,000 working.

[b] Cost of electricity at power plant bus bar.

Table B-58. Economics for Power - Fertilizer Company Cooperative Venture Annual Manufacturing Costs for 26-19-0 Fertilizer Made with Ammonium Sulfate Solution and Sulfur Dioxide Obtained by Scrubbing Power Plant Stack Gas[a]—Process B

(200-mw existing power unit, 3.5% S in coal; 97,100 tons/yr fertilizer)

	Annual quantity	Unit cost, $	Total annual cost, $	$/ton of fertilizer
Direct Costs				
Delivered raw material				
Ammonia	20.6 M tons	35.00/ton	721,400	7.430
Phosphate rock	59.8 M tons	12.88/ton	770,800	7.938
Ammonium sulfate solution (and SO_2 at minimum transfer price)	73.9 M tons	4.12/ton	304,000	3.131
Conditioner	1.9 M tons	46.60/ton	90,500	0.932
Antifoam	48.0 M lb	0.20/lb	9,600	0.099
Nitric acid catalyst	160 troy oz	120/troy oz	19,200	0.198
Subtotal raw material			1,915,500	19.728
Conversion costs				
Operating labor and supervision	70,900 man-hr	4.50/man-hr	319,100	3.286
Utilities				
Steam	339,700 M lb	0.60/M lb[b]	203,800	2.099
Water	1,764,840 M gal	0.06/M gal	105,900	1.091
Electricity	13,350,000 kwh	0.006/kwh[b]	80,100	0.825
Maintenance				
Labor and material			409,600	4.218
Analyses			21,000	0.216
Subtotal conversion costs			1,139,500	11.735
Subtotal direct costs			3,055,000	31.463
Indirect Costs				
Depreciation at 10% of fixed investment			879,400	9.057
Local taxes and insurance at 2% of fixed investment			175,900	1.812
Overhead				
Plant, 20% of conversion costs			227,900	2.347
Administrative, research, and service, 10% of conversion costs			114,000	1.174
Subtotal indirect costs			1,397,200	14.390
Total annual manufacturing costs for 26-19-0 fertilizer			4,452,200	45.853

[a] Basis:
Fertilizer plant on-stream time—7,000 hr/yr.
Midwest plant location—1969 costs.
Fertilizer capital investment—$8,794,000 fixed; $841,000 working.

[b] Cost of power and steam from power plant.

Table B-59. Economics for Power - Fertilizer Company Cooperative Venture Average Annual Operating Costs for Scrubbing Power Plant Stack Gas to Produce Ammonium Sulfate Solution and Sulfur Dioxide[a]—Process B

(500-mw new power unit, 2.0% S in coal;
58,835 tons ammonium sulfate/yr;
41,000 tons sulfur dioxide/yr)

	Annual quantity	Unit cost, $	Total annual cost, $	Cost/ton of coal burned, $
Direct Costs				
Delivered raw material				
Ammonia	15.5 M tons	35.00/ton	542,500	0.414
Conversion costs				
Operating labor and supervision	13,000 man-hr	4.50/man-hr	58,500	0.045
Utilities				
Water	123,000 M gal	0.05/M gal	6,200	0.005
Electricity	33,673,500 kwh	0.005/kwh[b]	168,400	0.129
Maintenance				
Labor and material			215,200	0.164
Analyses			10,000	0.008
Subtotal conversion costs			458,300	0.351
Subtotal direct costs			1,000,800	0.765
Indirect Costs				
Average capital charges at 14.5% of fixed investment			780,100	0.595
Overhead				
Plant, 20% of conversion costs			91,700	0.070
Administrative, 10% of operating labor			5,900	0.004
Subtotal indirect costs			877,700	0.669

	Cost/ton of ammonium sulfate and sulfur dioxide, $	Total annual cost, $	Cost/ton of coal burned, $
Total annual operating costs for ammonium sulfate solution and sulfur dioxide	18.816	1,878,500	1.434
Cost of air pollution control by alternate wet scrubbing - limestone process	13.235	1,321,300	1.008
Minimum expected transfer price of ammonium sulfate solution and sulfur dioxide to fertilizer plant	5.581	557,200	0.426

[a] Basis:
Remaining life of power plant– 35 years.
Coal burned–1,310,000 tons/yr–0.75 lb/kwh.
Stack gas reheat from 118° to 250° F., indirect liquid-gas method.
Power unit on-stream time–7,000 hr.
Midwest plant location–1969 costs.
Capital investment–$5,380,000 fixed; $54,800 working.

[b] Cost of electricity at power plant bus bar.

Table B-60. Economics for Power - Fertilizer Company Cooperative Venture Annual Manufacturing Costs for 26-19-0 Fertilizer Made with Ammonium Sulfate Solution and Sulfur Dioxide Obtained by Scrubbing Power Plant Stack Gas[a]—Process B

(500-mw new power unit, 2.0% S in coal; 131,300 tons/yr fertilizer)

	Annual quantity	Unit cost, $	Total annual cost, $	$/ton of fertilizer
Direct Costs				
Delivered raw material				
Ammonia	28.0 M tons	35.00/ton	978,000	7.449
Phosphate rock	81.0 M tons	12.48/ton	1,010,900	7.699
Ammonium sulfate solution (and SO_2 at minimum transfer price)	99.8 M tons	5.58/ton	557,200	4.244
Conditioner	2.6 M tons	46.60/ton	122,400	0.932
Antifoam	64.4 M lb	0.20/lb	13,000	0.099
Nitric acid catalyst	215 troy oz	120/troy oz	25,900	0.197
Subtotal raw material			2,707,400	20.620
Conversion costs				
Operating labor and supervision	74,700 man-hr	4.50/man-[illegible]	336,100	2.560
Utilities				
Steam	462,770 M lb	0.40/M lb[b]	185,100	1.410
Water	2,506,620 M gal	0.05/M gal	125,300	0.954
Electricity	16,548,000 kwh	0.005/kwh[b]	82,700	0.630
Maintenance				
Labor and material			474,800	3.616
Analyses			30,000	0.228
Subtotal conversion costs			1,234,000	9.398
Subtotal direct costs			3,941,400	30.018
Indirect Costs				
Depreciation at 10% of fixed investment			1,019,400	7.764
Local taxes and insurance at 2% of fixed investment			203,900	1.553
Overhead				
Plant, 20% of conversion costs			246,800	1.880
Administrative, research, and service, 10% of conversion costs			123,400	0.940
Subtotal indirect costs			1,593,500	12.137
Total annual manufacturing costs for 26-19-0 fertilizer			5,534,900	42,155

[a] Basis:
Fertilizer plant on-stream time–7,000 hr/yr.
Midwest plant location–1969 costs.
Fertilizer capital investment–$10,194,000 fixed; $1,116,000 working.

[b] Cost of power and steam from power plant.

Table B-61. Economics for Power - Fertilizer Company Cooperative Venture Average Annual Operating Costs for Scrubbing Power Plant Stack Gas to Produce Ammonium Sulfate Solution and Sulfur Dioxide[a]—Process B

(500-mw new power unit, 3.5% S in coal;
103,000 tons ammonium sulfate/yr;
71,820 tons sulfur dioxide/yr)

	Annual Quantity	Unit cost, $	Total annual cost, $	Cost/ton of coal burned, $
Direct Costs				
Delivered raw material				
Ammonia	27.2 M tons	35.00/ton	952,000	0.727
Conversion costs				
Operating labor and supervision	13,300 man-hr	4.50/man-hr	59,800	0.046
Utilities				
Water	132,300 M gal	0.05/M gal	6,600	0.005
Electricity	33,967,500 kwh	0.005/kwh[b]	169,800	0.130
Maintenance				
Labor and material			222,400	0.170
Analyses			16,000	0.012
Subtotal conversion costs			474,600	0.363
Subtotal direct costs			1,426,600	1.090
Indirect Costs				
Average capital charges at 14.5% of fixed investment			806,300	0.615
Overhead				
Plant, 20% of conversion costs			94,900	0.072
Administrative, 10% of operating labor			6,000	0.005
Subtotal indirect costs			907,200	0.692

	Cost/ton of ammonium sulfate and sulfur dioxide, $	Total annual cost, $	Cost/ton of coal burned, $
Total annual operating costs for ammonium sulfate solution and sulfur dioxide	13.352	2,333,800	1.782
Cost of air pollution control by alternate wet scrubbing - limestone process	9.246	1,616,100	1.234
Minimum expected transfer price of ammonium sulfate solution and sulfur dioxide to fertilizer plant	4.106	717,700	0.548

[a] Basis:
Remaining life of power plant—35 years.
Coal burned—1,310,000 tons/yr—0.75 lb/kwh.
Stack gas reheat from 118° to 250°F., indirect liquid-gas method.
Power unit on-stream time—7,000 hr.
Midwest plant location—1969 costs.
Capital investment—$5,561,000 fixed; $85,000 working.

[b] Cost of electricity at power plant bus bar.

Table B-62. Economics for Power - Fertilizer Company Cooperative Venture Annual Manufacturing Costs for 26-19-0 Fertilizer Made with Ammonium Sulfate Solution and Sulfur Dioxide Obtained by Scrubbing Power Plant Stack Gas[a]—Process B

(500-mw new power unit, 3.5% S in coal;
230,000 tons/yr fertilizer)

	Annual quantity	Unit cost, $	Total annual cost, $	$/ton of fertilizer
Direct Costs				
Delivered raw material				
Ammonia	48.9 M tons	35.00/ton	1,711,500	7.441
Phosphate rock	141.8 M tons	11.88/ton	1,684,600	7.324
Ammonium sulfate solution (and SO_2 at minimum transfer price)	174.8 M tons	4.11/ton	717,700	3.120
Conditioner	4.6 M tons	46.60/ton	214,400	0.932
Antifoam	113.4 M lb	0.18/lb	20,400	0.089
Nitric acid catalyst	377 troy oz	120/troy oz	45,200	0.197
Subtotal raw material			4,393,800	19.103
Conversion costs				
Operating labor and supervision	88,680 man-hr	4.50/man-hr	399,100	1.735
Utilities				
Steam	805,070 M lb	0.40/M lb[b]	322,000	1.400
Water	4,347,000 M gal	0.05/M gal	217,400	0.945
Electricity	27,326,250 kwh	0.005/kwh[b]	136,700	0.594
Maintenance				
Labor and material			658,600	2.864
Analyses			49,000	0.213
Subtotal conversion costs			1,782,800	7.751
Subtotal direct costs			6,176,600	26.854
Indirect Costs				
Depreciation at 10% of fixed investment			1,412,800	6.143
Local taxes and insurance at 2% of fixed investment			282,600	1.229
Overhead				
Plant, 20% of conversion costs			356,600	1.550
Administrative, research, and service, 10% of conversion costs			178,300	0.775
Subtotal indirect costs			2,230,300	9.697
Total annual manufacturing costs for 26-19-0 fertilizer			8,406,900	36.551

[a] Basis:
Fertilizer plant on-stream time—7,000 hr/yr.
Midwest plant location—1969 costs.
Fertilizer capital investment—$14,128,000 fixed; $1,805,000 working.

[b] Cost of power and steam from power plant.

Table B-63. Economics for Power - Fertilizer Company Cooperative Venture
Average Annual Operating Costs for Scrubbing Power Plant Stack Gas
to Produce Ammonium Sulfate Solution and Sulfur Dioxide[a]—Process B

(500-mw existing power unit, 3.5% S in coal;
105,370 tons ammonium sulfate/yr;
73,470 tons sulfur dioxide/yr)

	Annual quantity	Unit cost, $	Total annual cost, $	Cost/ton of coal burned, $
Direct Costs				
Delivered raw material				
Ammonia	27.8 M tons	35.00/ton	972,500	0.726
Conversion costs				
Operating labor and supervision	13,540 man-hr	4.50/man-hr	60,900	0.046
Utilities				
Water	251,300 M gal	0.06/M gal	15,100	0.011
Electricity	35,640,000 kwh	0.005/kwh[b]	178,200	0.133
Maintenance				
Labor and material			234,400	0.175
Analyses			16,000	0.012
Subtotal conversion costs			504,600	0.377
Subtotal direct costs			1,477,100	1.103
Indirect Costs				
Average capital charges at 14.8% of fixed investment			867,300	0.647
Overhead				
Plant, 20% of conversion costs			100,900	0.075
Administrative, 10% of operating labor			6,100	0.005
Subtotal indirect costs			974,300	0.727

	Cost/ton of ammonium sulfate and sulfur dioxide, $	Total annual cost, $	Cost/ton of coal burned, $
Total annual operating costs for ammonium sulfate solution and sulfur dioxide	13.707	2,451,400	1.830
Cost of air pollution control by alternate wet scrubbing - limestone process	9.491	1,697,300	1.267
Minimum expected transfer price of ammonium sulfate solution and sulfur dioxide to fertilizer plant	4.216	754,100	0.563

[a] Basis:
Remaining life of power plant—32 years.
Coal burned—1,339,600 tons/yr—0.767 lb/kwh.
Stack gas reheat from 118° to 250° F., indirect liquid-gas method.
Power unit on-stream time—7,000 hr.
Midwest plant location—1969 costs.
Capital investment—$5,860,000 fixed; $85,000 working.

[b] Cost of electricity at power plant bus bar.

Table B-64. Economics for Power - Fertilizer Company Cooperative Venture Annual Manufacturing Costs for 26-19-0 Fertilizer Made with Ammonium Sulfate Solution and Sulfur Dioxide Obtained by Scrubbing Power Plant Stack Gas[a]—Process B

(500-mw existing power unit, 3.5% S in coal;
235,800 tons/yr fertilizer)

	Annual quantity	Unit cost, $	Total annual cost, $	$/ton of fertilizer
Direct Costs				
Delivered raw material				
Ammonia	50.2 M tons	35.00/ton	1,758,100	7.456
Phosphate rock	145.4 M tons	11.88/ton	1,727,000	7.324
Ammonium sulfate solution (and SO_2 at minimum transfer price)	178.8 M tons	4.22/ton	754,100	3.198
Conditioner	4.7 M tons	46.60/ton	219,800	0.932
Antifoam	116.7 M lb	0.18/lb	21,000	0.089
Nitric acid catalyst	385 troy oz	120/troy oz	46,200	0.196
Subtotal raw material			4,526,200	19.195
Conversion costs				
Operating labor and supervision	88,900 man-hr	4.50/man-hr	400,100	1.697
Utilities				
Steam	825,400 M lb	0.50/M lb[b]	412,700	1.750
Water	4,347,000 M gal	0.06/M gal	260,800	1.106
Electricity	28,020,000 kwh	0.005/kwh[b]	140,100	0.594
Maintenance				
Labor and material			667,600	2.831
Analyses			49,000	0.208
Subtotal conversion costs			1,930,300	8.186
Subtotal direct costs			6,456,500	27.381
Indirect Costs				
Depreciation at 10% of fixed investment			1,433,100	6.078
Local taxes and insurance at 2% of fixed investment			286,600	1.215
Overhead				
Plant, 20% of conversion costs			386,100	1.637
Administrative, research, and service, 10% of conversion costs			193,000	0.819
Subtotal indirect costs			2,298,800	9.749
Total annual manufacturing costs for 26-19-0 fertilizer			8,755,300	37.130

[a] Basis:
Fertilizer plant on-stream time—7,000 hr/yr.
Midwest plant location—1969 costs.
Fertilizer capital investment—$14,331,000 fixed; $1,852,700 working.

[b] Cost of power and steam from power plant.

Table B-65. Economics for Power - Fertilizer Company Cooperative Venture Average Annual Operating Costs for Scrubbing Power Plant Stack Gas to Produce Ammonium Sulfate Solution and Sulfur Dioxide[a]—Process B

(500-mw new power unit, 5.0% S in coal;
147,250 tons ammonium sulfate/yr;
102,630 tons sulfur dioxide/yr)

	Annual quantity	Unit cost, $	Total annual cost, $	Cost/ton of coal burned, $
Direct Costs				
Delivered raw material				
Ammonia	38.9 M tons	30.00/ton	1,167,000	0.891
Conversion costs				
Operating labor and supervision	13,600 man-hr	4.50/man-hr	61,200	0.047
Utilities				
Water	141,960 M gal	0.04/M gal	5,700	0.004
Electricity	34,251,000 kwh	0.005/kwh[b]	171,300	0.131
Maintenance				
Labor and material			228,600	0.175
Analyses			22,000	0.017
Subtotal conversion costs			488,800	0.374
Subtotal direct costs			1,655,800	1.265
Indirect Costs				
Average capital charges at 14.5% of fixed investment			828,800	0.633
Overhead				
Plant, 20% of conversion costs			97,800	0.075
Administrative, 10% of operating labor			6,100	0.005
Subtotal indirect costs			932,700	0.713

	Cost/ton of ammonium sulfate and sulfur dioxide, $	Total annual cost, $	Cost/ton of coal burned, $
Total annual operating costs for ammonium sulfate solution and sulfur dioxide	10.358	2,588,500	1.978
Cost of air pollution control by alternate wet scrubbing - limestone process	7.679	1,918,900	1.465
Minimum expected transfer price of ammonium sulfate solution and sulfur dioxide to fertilizer plant	2.679	669,600	0.513

[a] Basis:
Remaining life of power plant – 35 years.
Coal burned – 1,310,000 tons/yr – 0.75 lb/kwh.
Stack gas reheat from 118° to 250° F., indirect liquid-gas method.
Power unit on-stream time – 7,000 hr.
Midwest plant location – 1969 costs.
Capital investment – $5,716,000 fixed; $104,100 working.

[b] Cost of electricity at power plant bus bar.

Table B-66. Economics for Power - Fertilizer Company Cooperative Venture Annual Manufacturing Costs for 26-19-0 Fertilizer Made with Ammonium Sulfate Solution and Sulfur Dioxide Obtained by Scrubbing Power Plant Stack Gas[a]—Process B

(500-mw new power unit, 5.0% S in coal; 328,600 tons/yr fertilizer)

	Annual quantity	Unit cost, $	Total annual cost, $	$/ton of fertilizer
Direct Costs				
Delivered raw material				
Ammonia	69.9 M tons	30.00/ton	2,094,700	6.375
Phosphate rock	202.7 M tons	11.88/ton	2,406,600	7.324
Ammonium sulfate solution (and SO_2 at minimum transfer price)	249.9 M tons	2.68/ton	669,600	2.038
Conditioner	6.6 M tons	46.60/ton	306,300	0.932
Antifoam	161.7 M lb	0.15/lb	24,300	0.074
Nitric acid catalyst	540 troy oz	120/troy oz	64,800	0.197
Subtotal raw material			5,566,300	16.940
Conversion costs				
Operating labor and supervision	103,900 man-hr	4.50/man-hr	467,500	1.423
Utilities				
Steam	1,148,000 M lb	0.40/M lb[b]	459,200	1.397
Water	6,584,760 M gal	0.04/M gal	263,400	0.802
Electricity	39,469,500 kwh	0.005/kwh[b]	197,300	0.600
Maintenance				
Labor and material			829,400	2.524
Analyses			68,000	0.207
Subtotal conversion costs			2,284,800	6.953
Subtotal direct costs			7,851,100	23.893
Indirect Costs				
Depreciation at 10% of fixed investment			1,780,900	5.419
Local taxes and insurance at 2% of fixed investment			356,200	1.084
Overhead				
Plant, 20% of conversion costs			457,000	1.391
Administrative, research, and service, 10% of conversion costs			228,500	0.695
Subtotal indirect costs			2,822,600	8.589
Total annual manufacturing costs for 26-19-0 fertilizer			10,673,700	32.482

[a] Basis:
Fertilizer plant on-stream time—7,000 hr/yr.
Midwest plant location—1969 costs.
Fertilizer capital investment—$17,809,000 fixed; $2,289,000 working.

[b] Cost of power and steam from power plant.

Table B-67. Economics for Power - Fertilizer Company Cooperative Venture Average Annual Operating Costs for Scrubbing Power Plant Stack Gas to Produce Ammonium Sulfate Solution and Sulfur Dioxide[a]—Process B

(1000-mw new power unit, 3.5% S in coal;
199,200 tons ammonium sulfate/yr;
138,900 tons sulfur dioxide/yr)

	Annual quantity	Unit cost, $	Total annual cost, $	Cost/ton of coal burned, $
Direct Costs				
Delivered raw material				
Ammonia	52.6 M tons	30.00/ton	1,576,600	0.621
Conversion Costs				
Operating labor and supervision	16,000 man-hr	4.50/man-hr	72,000	0.028
Utilities				
Water	244,500 M gal	0.04/M gal	9,800	0.004
Electricity	65,367,900 kwh	0.004/kwh[b]	261,500	0.103
Maintenance				
Labor and material			342,600	0.135
Analyses			30,000	0.012
Subtotal conversion costs			715,900	0.282
Subtotal direct costs			2,292,500	0.903
Indirect Costs				
Average capital charges at 14.5% of fixed investment			1,241,900	0.490
Overhead				
Plant, 20% of conversion costs			143,200	0.056
Administrative, 10% of operating labor			7,200	0.003
Subtotal indirect costs			1,392,300	0.549

	Cost/ton of ammonium sulfate and sulfur dioxide, $	Total annual cost, $	Cost/ton of coal burned, $
Total annual operating costs for ammonium sulfate solution and sulfur dioxide	10.899	3,684,800	1.452
Cost of air pollution control by alternate wet scrubbing - limestone process	7.601	2,569,900	1.013
Minimum expected transfer price of ammonium sulfate solution and sulfur dioxide to fertilizer plant	3.298	1,114,900	0.439

[a] Basis:
Remaining life of power plant – 35 years.
Coal burned – 2,537,300 tons/yr – 0.725 lb/kwh.
Stack gas reheat from 118° to 250° F., indirect liquid-gas method.
Power unit on-stream time – 7,000 hr.
Midwest plant location – 1969 costs.
Capital investment – $8,565,000 fixed; $145,800 working.

[b] Cost of electricity at power plant bus bar.

Table B-68. Economics for Power - Fertilizer Company Cooperative Venture Annual Manufacturing Costs for 26-19-0 Fertilizer Made with Ammonium Sulfate Solution and Sulfur Dioxide Obtained by Scrubbing Power Plant Stack Gas[a]—Process B

(1000-mw new power unit, 3.5% S in coal;
444,000 tons/yr fertilizer)

	Annual quantity	Unit cost, $	Total annual cost, $	$/ton of fertilizer
Direct Costs				
Delivered raw material				
Ammonia	94.3 M tons	30.00/ton	2,830,500	6.375
Phosphate rock	273.7 M tons	11.88/ton	3,251,900	7.324
Ammonium sulfate solution (and SO_2 at minimum transfer price)	338.1 M tons	3.30/ton	1,114,900	2.511
Conditioner	8.9 M tons	46.60/ton	413,800	0.932
Antifoam	219.3 M lb	0.15/lb	32,900	0.074
Nitric acid catalyst	733 troy oz	120/troy oz	87,900	0.198
Subtotal raw material			7,731,900	17.414
Conversion costs				
Operating labor and supervision	120,700 man-hr	4.50/man-hr	543,200	1.223
Utilities				
Steam	1,678,300 M lb	0.30/M lb[b]	503,500	1.134
Water	8,435,500 M gal	0.04/M gal	337,400	0.760
Electricity	34,207,100 kwh	0.004/kwh[b]	136,800	0.308
Maintenance				
Labor and material			1,032,400	2.325
Analyses			90,000	0.203
Subtotal conversion costs			2,643,300	5.953
Subtotal direct costs			10,375,200	23.367
Indirect Costs				
Depreciation at 10% of fixed investment			2,243,500	5.053
Local taxes and insurance at 2% of fixed investment			448,700	1.011
Overhead				
Plant, 20% of conversion costs			528,700	1.191
Administrative, research, and service, 10% of conversion costs			264,300	0.595
Subtotal indirect costs			3,485,200	7.850
Total annual manufacturing costs for 26-19-0 fertilizer			13,860,400	31.217

[a] Basis:
Fertilizer plant on-stream time–7,000 hr/yr.
Midwest plant location–1969 costs.
Fertilizer capital investment–$22,435,000 fixed; $3,098,400 working.

[b] Cost of power and steam from power plant.

Table B-69. Economics for Power - Fertilizer Company Cooperative Venture Average Annual Operating Costs for Scrubbing Power Plant Stack Gas to Produce Ammonium Sulfate Solution and Sulfur Dioxide[a]—Process B

(1000-mw existing power unit, 3.5% S in coal;
206,000 tons ammonium sulfate/yr;
143,600 tons sulfur dioxide/yr)

	Annual quantity	Unit cost, $	Total annual cost, $	Cost/ton of coal burned, $
Direct Costs				
Delivered raw material				
Ammonia	54.4 M tons	30.00/ton	1,633,500	0.622
Conversion costs				
Operating labor and supervision	16,100 man-hr	4.50/man-hr	72,400	0.028
Utilities				
Water	264,600 M gal	0.05/M gal	13,200	0.005
Electricity	69,546,750 kwh	0.004/kwh[b]	278,200	0.106
Maintenance				
Labor and material			370,200	0.141
Analyses			30,000	0.011
Subtotal conversion costs			764,000	0.291
Subtotal direct costs			2,397,500	0.913
Indirect Costs				
Average capital charges at 14.8% of fixed investment			1,369,700	0.521
Overhead				
Plant, 20% of conversion costs			152,800	0.058
Administrative, 10% of operating labor			7,200	0.003
Subtotal indirect costs			1,529,700	0.582

	Cost/ton of ammonium sulfate and sulfur dioxide, $	Total annual cost, $	Cost/ton of coal burned, $
Total annual operating costs for ammonium sulfate solution and sulfur dioxide	11.233	3,927,200	1.495
Cost of air pollution control by alternate wet scrubbing - limestone process	7.819	2,733,400	1.041
Minimum expected transfer price of ammonium sulfate solution and sulfur dioxide to fertilizer plant	3.414	1,193,800	0.454

[a] Basis:
Remaining life of power plant - 32 years.
Coal burned - 2,625,000 tons/yr - 0.75 lb/kwh.
Stack gas reheat from 118° to 250° F., indirect liquid-gas method.
Power unit on-stream time - 7,000 hr.
Midwest plant location - 1969 costs.
Capital investment - $9,255,000 fixed; $145,800 working.

[b] Cost of electricity at power plant bus bar.

Table B-70. Economics for Power - Fertilizer Company Cooperative Venture Annual Manufacturing Costs for 26-19-0 Fertilizer Made with Ammonium Sulfate Solution and Sulfur Dioxide Obtained by Scrubbing Power Plant Stack Gas[a]—Process B

(1000-mw existing power unit, 3.5% S in coal:
460,000 tons/yr fertilizer)

	Annual quantity	Unit cost, $	Total annual cost, $	$/ton of fertilizer
Direct Costs				
Delivered raw material				
Ammonia	97.8 M tons	30.00/ton	2,932,500	6.375
Phosphate rock	283.6 M tons	11.88/ton	3,369,200	7.324
Ammonium sulfate solution (and SO_2 at minimum transfer price)	349.6 M tons	3.41/ton	1,193,800	2.595
Conditioner	9.2 M tons	46.60/ton	428,700	0.932
Antifoam	226.8 M lb	0.15/lb	34,000	0.074
Nitric acid catalyst	760 troy oz	120/troy oz	91,200	0.198
Subtotal raw material			8,049,400	17.498
Conversion costs				
Operating labor and supervision	121,000 man-hr	4.50/man-hr	547,200	1.190
Utilities				
Steam	1,739,500 M lb	0.45/M lb[b]	782,800	1.702
Water	8,723,400 M gal	0.05/M gal	436,200	0.948
Electricity	35,394,500 kwh	0.004/kwh[b]	141,600	0.308
Maintenance				
Labor and material			1,092,800	2.376
Analyses			90,000	0.195
Subtotal conversion costs			3,090,600	6.719
Subtotal direct costs			11,140,000	24.217
Indirect Costs				
Depreciation at 10% of fixed investment			2,374,900	5.163
Local taxes and insurance at 2% of fixed investment			475,000	1.032
Overhead				
Plant, 20% of conversion costs			618,100	1.344
Administrative, research, and service, 10% of conversion costs			309,100	0.672
Subtotal indirect costs			3,777,100	8.211
Total annual manufacturing costs for 26-19-0 fertilizer			14,917,100	32.428

[a] Basis:
Fertilizer plant on-stream time—7,000 hr/yr.
Midwest plant location—1969 costs.
Fertilizer capital investment—$23,749,000 fixed; $3,213,000 working.

[b] Cost of power and steam from power plant.

Table B-71. Economics for Power - Fertilizer Company Cooperative Venture Average Annual Operating Costs for Scrubbing Power Plant Stack Gas to Produce Ammonium Sulfate Solution[a]—Process C

(200-mw existing power unit, 3.5% S in coal; 65,860 tons ammonium sulfate/yr)

	Annual quantity	Unit cost, $	Total annual cost, $	Cost/ton of coal burned, $
Direct Costs				
Delivered raw material				
Ammonia	11.04 M tons	35.00/ton	386,400	0.697
Conversion costs				
Operating labor and supervision	10,170 man-hr	4.50/man-hr	45,800	0.083
Utilities				
Water	776,200 M gal	0.06/M gal	46,600	0.084
Electricity	21,094,500 kwh	0.006/kwh[b]	126,600	0.228
Maintenance				
Labor and material			115,200	0.208
Analyses			12,000	0.022
Subtotal conversion costs			346,200	0.625
Subtotal direct costs			732,600	1.322
Indirect Costs				
Average capital charges at 15.1% of fixed investment			434,900	0.784
Overhead				
Plant, 20% of conversion costs			69,200	0.125
Administrative, 10% of operating labor			4,600	0.008
Subtotal indirect costs			508,700	0.917
		Cost/ton of ammonium sulfate, $	Total annual cost, $	Cost/ton of coal burned, $
Total annual operating costs for ammonium sulfate solution		18.848	1,241,300	2.239
Cost of air pollution control by alternate wet-limestone scrubbing process		12.396	816,400	1.473
Minimum expected transfer price of ammonium sulfate solution to fertilizer plant		6.452	424,900	0.766

[a] Basis:
Remaining life of power plant—27 years.
Coal burned—554,400 tons/yr—0.792 lb/kwh.
Stack gas reheat from 118° to 250° F., indirect liquid-gas method.
Power unit on-stream time—7,000 hr.
Midwet plant location—1969 costs.
Capital investment—$2,880,000 fixed; $162,000 working.

[b] Cost of electricity at power plant bus bar.

Table B-72. Economics for Power - Fertilizer Company Cooperative Venture Annual Manufacturing Costs for 19-14-0 Fertilizer Made with Ammonium Sulfate Solution Obtained by Scrubbing Power Plant Stack Gas[a]—Process C

(200-mw existing power unit, 3.5% S in coal; 56,700 tons/yr fertilizer)

	Annual quantity	Unit cost, $	Total annual cost, $	$/ton of fertilizer
Direct Costs				
Delivered raw material				
Ammonia	3.4 M tons	35.00/ton	119,000	2.099
Phosphate rock	25.5 M tons	13.88/ton	343,900	6.065
Ammonium sulfate (solution at minimum transfer price)	65.9 M tons	6.45/ton	424,900	7.494
Conditioner	1.1 M tons	46.60/ton	51,300	0.905
Subtotal raw material			939,100	16.563
Conversion costs				
Operating labor and supervision	59,600 man-hr	4.50/man-hr	268,200	4.730
Utilities				
Net heat from boiler	358,400 MM Btu	0.60/MM Btu	215,000	3.792
Water	3,154,200 M gal	0.06/M gal	189,300	3.339
Electricity	17,682,000 kwh	0.006/kwh[b]	106,100	1.871
Maintenance				
Labor and material			301,900	5.324
Analyses			3,900	0.069
Subtotal conversion costs			1,084,400	19.125
Subtotal direct costs			2,023,500	35.688
Indirect Costs				
Depreciation at 10% of fixed investment			671,000	11.834
Local taxes and insurance at 2% of fixed investment			134,200	2.367
Overhead				
Plant, 20% of conversion costs			216,800	3.824
Administrative, research, and service, 10% of conversion costs			108,400	1.912
Subtotal indirect costs			1,130,400	19.937
Total annual manufacturing costs for 19-14-0 fertilizer			3,153,900	55.625

[a] Fertilizer plant on-stream time—7,000 hr/yr.
Midwest plant location—1969 costs.
Fertilizer capital investment—$6,709,500 fixed; $444,000 working.
[b] Cost of power and heat from power plant.

Table B-73. Economics for Power - Fertilizer Company Cooperative Venture Average Annual Operating Costs for Scrubbing Power Plant Stack Gas to Produce Ammonium Sulfate Solution[a]—Process C

(500-mw new power unit, 2.0% S in coal; 89,000 tons ammonium sulfate/yr)

	Annual quantity	Unit cost, $	Total annual cost, $	Cost/ton of coal burned, $
Direct Costs				
Delivered raw material				
Ammonia	14.9 M tons	35.00/ton	521,400	0.398
Conversion costs				
Operating labor and supervision	12,320 man-hr	4.50/man-hr	55,400	0.042
Utilities				
Water	1,160,900 M gal	0.05/M gal	58,000	0.044
Electricity	42,987,000 kwh	0.005/kwh[b]	214,900	0.164
Maintenance				
Labor and material			220,600	0.168
Analyses			15,000	0.011
Subtotal conversion costs			563,900	0.429
Subtotal direct costs			1,085,300	0.827
Indirect Costs				
Average capital charges at 14.5% of fixed investment			799,800	0.611
Overhead				
Plant, 20% of conversion costs			112,800	0.086
Administrative, 10% of operating labor			5,500	0.004
Subtotal indirect costs			918,100	0.701

	Cost/ton of ammonium sulfate, $	Total annual cost, $	Cost/ton of coal burned, $
Total annual operating costs for ammonium sulfate solution	22.510	2,003,400	1.528
Cost of air pollution control by alternate wet-limestone scrubbing process	14.846	1,321,300	1.008
Minimum expected transfer price of ammonium sulfate solution to fertilizer plant	7.664	682,100	0.520

[a] Basis:
Remaining life of power plant—35 years.
Coal burned—1,310,000 tons/yr—0.75 lb/kwh.
Stack gas reheat from 118° to 250° F., indirect liquid-gas method.
Power unit on-stream time—7,000 hr.
Midwest plant location—1969 costs.
Capital investment—$5,516,000 fixed; $230,000 working.

[b] Cost of electricity at power plant bus bar.

Table B-74. Economics for Power - Fertilizer Company Cooperative Venture Annual Manufacturing Costs for 19-14-0 Fertilizer Made with Ammonium Sulfate Solution Obtained by Scrubbing Power Plant Stack Gas[a]—Process C

(500-mw new power unit, 2.0% S in coal; 76,600 tons/yr fertilizer)

	Annual quantity	Unit cost, $	Total annual cost, $	$/ton of fertilizer
Direct Costs				
Delivered raw material				
Ammonia	4.6 M tons	35.00/ton	161,000	2.102
Phosphate rock	34.4 M tons	13.88/ton	477,500	6.234
Ammonium sulfate (solution at minimum transfer price)	89.0 M tons	7.66/ton	682,100	8.905
Conditioner	1.5 M tons	46.60/ton	69,900	0.913
Subtotal raw material			1,390,500	18.154
Conversion costs				
Operating labor and supervision	61,400 man-hr	4.50/man-hr	276,300	3.607
Utilities				
Net heat from boiler	484,000 MM Btu	0.40/MM Btu	193,600	2.527
Water	4,342,800 M gal	0.05/M gal	217,100	2.834
Electricity	25,074,000 kwh	0.005/kwh[b]	125,400	1.637
Maintenance				
Labor and material			339,400	4.431
Analyses			4,000	0.052
Subtotal conversion costs			1,155,800	15.088
Subtotal direct costs			2,546,300	33.242
Indirect Costs				
Depreciation at 10% of fixed investment			754,100	9.845
Local taxes and insurance at 2% of fixed investment			150,800	1.969
Overhead				
Plant, 20% of conversion costs			231,200	3.018
Administrative, research, and service, 10% of conversion costs			115,600	1.509
Subtotal indirect costs			1,251,700	16.341
Total annual manufacturing costs for 19-14-0 fertilizer			3,798,000	49.583

[a] Fertilizer plant on-stream time—7,000 hr/yr.
Midwest plant location—1969 costs.
Fertilizer capital investment—$7,541,300 fixed; $550,000 working.

[b] Cost of power and heat from power plant.

Table B-75. Economics for Power - Fertilizer Company Cooperative Venture Average Annual Operating Costs for Scrubbing Power Plant Stack Gas to Produce Ammonium Sulfate Solution[a]—Process C

(500-mw new power unit, 3.5% S in coal;
155,925 tons ammonium sulfate/yr)

	Annual quantity	Unit cost, $	Total annual cost, $	Cost/ton of coal burned, $
Direct Costs				
Delivered raw material				
Ammonia	26.1 M tons	35.00/ton	913,500	0.697
Conversion costs				
Operating labor and supervision	12,590 man-hr	4.50/man-hr	56,700	0.043
Utilities				
Water	1,940,000 M gal	0.05/M gal	97,000	0.074
Electricity	48,892,900 kwh	0.005/kwh[b]	244,500	0.187
Maintenance				
Labor and material			237,400	0.181
Analyses			25,000	0.019
Subtotal conversion costs			660,600	0.504
Subtotal direct costs			1,574,100	1.201
Indirect Costs				
Average capital charges at 14.5% of fixed investment			860,700	0.657
Overhead				
Plant, 20% of conversion costs			132,100	0.101
Administrative, 10% of operating labor			5,700	0.004
Subtotal indirect costs			998,500	0.762

	Cost/ton of ammonium sulfate, $	Total annual cost, $	Cost/ton of coal burned, $
Total annual operating costs for ammonium sulfate solution	16.499	2,572,600	1.963
Cost of air pollution control by alternate wet-limestone scrubbing process	10.365	1,616,100	1.233
Minimum expected transfer price of ammonium sulfate solution to fertilizer plant	6.134	956,500	0.730

[a] Basis:
Remaining life of power plant—35 years.
Coal burned—1,310,000 tons/yr—0.75 lb/kwh.
Stack gas reheat from 118° to 250° F., indirect liquid-gas method.
Power unit on-stream time—7,000 hr.
Midwest plant location—1969 costs.
Capital investment—$5,936,000 fixed; $335,000 working.

[b] Cost of electricity at power plant bus bar.

Table B-76. Economics for Power - Fertilizer Company Cooperative Venture Annual Manufacturing Costs for 19-14-0 Fertilizer Made with Ammonium Sulfate Solution Obtained by Scrubbing Power Plant Stack Gas[a]—Process C

(500-mw new power unit, 3.5% S in coal;
134,000 tons/yr fertilizer)

	Annual quantity	Unit cost, $	Total annual cost, $	$/ton of fertilizer
Direct Costs				
Delivered raw material				
Ammonia	8.1 M tons	35.00/ton	283,500	2.116
Phosphate rock	60.2 M tons	12.68/ton	763,300	5.696
Ammonium sulfate (solution at minimum transfer price)	155.9 M tons	6.13/ton	956,500	7.138
Conditioner	2.7 M tons	46.60/ton	125,800	0.939
Subtotal raw material			2,129,100	15.889
Conversion costs				
Operating labor and supervision	70,000 man-hr	4.50/man-hr	315,000	2.351
Utilities				
Net heat from boiler	847,000 MM Btu	0.40/MM Btu	338,800	2.528
Water	7,576,800 M gal	0.05/M gal	378,800	2.827
Electricity	43,589,000 kwh	0.005/kwh[b]	217,900	1.626
Maintenance				
Labor and material			468,900	3.499
Analyses			8,100	0.060
Subtotal conversion costs			1,727,500	12.891
Subtotal direct costs			3,856,600	28.780
Indirect Costs				
Depreciation at 10% of fixed investment			1,042,100	7.777
Local taxes and insurance at 2% of fixed investment			208,400	1.555
Overhead				
Plant, 20% of conversion costs			345,500	2.578
Administrative, research, and service, 10% of conversion costs			172,800	1.290
Subtotal indirect costs			1,768,800	13.200
Total annual manufacturing costs for 19-14-0 fertilizer			5,625,400	41.980

[a] Fertilizer plant on-stream time—7,000 hr/yr.
Midwest plant location—1969 costs.
Fertilizer capital investment—$10,420,800 fixed; $850,000 working.
[b] Cost of power and heat from power plant.

Table B-77. Economics for Power - Fertilizer Company Cooperative Venture Average Annual Operating Costs for Scrubbing Power Plant Stack Gas to Produce Ammonium Sulfate Solution[a]—Process C

(500-mw existing power unit, 3.5% S in coal; 159,500 tons ammonium sulfate/yr)

	Annual quantity	Unit cost, $	Total annual cost, $	Cost/ton of coal burned, $
Direct Costs				
Delivered raw material				
Ammonia	26.7 M tons	35.00/ton	933,700	0.697
Conversion costs				
Operating labor and supervision	12,640 man-hr	4.50/man-hr	56,900	0.042
Utilities				
Water	1,940,000 M gal	0.06/M gal	116,400	0.087
Electricity	49,942,900 kwh	0.005/kwh[b]	249,700	0.186
Maintenance				
Labor and material			250,800	0.187
Analyses			25,000	0.019
Subtotal conversion costs			698,800	0.521
Subtotal direct costs			1,632,500	1.218
Indirect Costs				
Average capital charges at 14.8% of fixed investment			927,800	0.693
Overhead				
Plant, 20% of conversion costs			139,800	0.104
Administrative, 10% of operating labor			5,700	0.004
Subtotal indirect costs			1,073,300	0.801

	Cost/ton of ammonium sulfate, $	Total annual cost, $	Cost/ton of coal burned, $
Total annual operating costs for ammonium sulfate solution	16.964	2,705,800	2.019
Cost of air pollution control by alternate wet-limestone scrubbing process	10.641	1,697,300	1.267
Minimum expected transfer price of ammonium sulfate solution to fertilizer plant	6.323	1,008,500	0.752

[a] Basis:
Remaining life of power plant—32 years.
Coal burned—1,339,600 tons/yr—0.767 lb/kwh.
Stack gas reheat from 118° to 250°F., indirect liquid-gas method.
Power unit on-stream time—7,000 hr.
Midwest plant location—1969 costs.
Capital investment—$6,269,000 fixed; $355,000 working.

[b] Cost of electricity at power plant bus bar.

Table B-78. Economics for Power - Fertilizer Company Cooperative Venture Annual Manufacturing Costs for 19-14-0 Fertilizer Made with Ammonium Sulfate Solution Obtained by Scrubbing Power Plant Stack Gas[a]—Process C

(500-mw existing power unit, 3.5% S in coal; 137,000 tons/yr fertilizer)

	Annual quantity	Unit cost, $	Total annual cost, $	$/ton of fertilizer
Direct Costs				
Delivered raw material				
Ammonia	8.3 M tons	35.00/ton	290,500	2.120
Phosphate rock	61.5 M tons	12.68/ton	779,800	5.692
Ammonium sulfate (solution at minimum transfer price)	159.5 M tons	6.32/ton	1,008,500	7.361
Conditioner	2.8 M tons	46.60/ton	130,500	0.953
Subtotal raw material			2,209,300	16.126
Conversion costs				
Operating labor and supervision	70,440 man-hr	4.50/man-hr	317,000	2.314
Utilities				
Net heat from boiler	866,000 MM Btu	0.50/MM Btu	433,000	3.161
Water	7,694,400 M gal	0.06/M gal	461,700	3.370
Electricity	44,114,000 kwh	0.005/kwh[b]	220,600	1.610
Maintenance				
Labor and material			497,700	3.633
Analyses			8,100	0.059
Subtotal conversion costs			1,938,100	14.147
Subtotal direct costs			4,147,400	30.273
Indirect Costs				
Depreciation at 10% of fixed investment			1,106,100	8.074
Local taxes and insurance at 2% of fixed investment			221,200	1.614
Overhead				
Plant, 20% of conversion costs			387,600	2.829
Administrative, research, and service, 10% of conversion costs			193,800	1.415
Subtotal indirect costs			1,908,700	13.932
Total annual manufacturing costs for 19-14-0 fertilizer			6,056,100	44.205

[a] Fertilizer plant on-stream time–7,000 hr/yr.
Midwest plant location–1969 costs.
Fertilizer capital investment–$11,060,600 fixed; $905,000 working.

[b] Cost of power and heat from power plant.

Table B-79. Economics for Power - Fertilizer Company Cooperative Venture Average Annual Operating Costs for Scrubbing Power Plant Stack Gas to Produce Ammonium Sulfate Solution[a]—Process C

(500-mw new power unit, 5.0% S in coal;
222,810 tons ammonium sulfate/yr)

	Annual quantity	Unit cost, $	Total annual cost, $	Cost/ton of coal burned, $
Direct Costs				
Delivered raw material				
Ammonia	37.2 M tons	35.00/ton	1,302,000	0.994
Conversion costs				
Operating labor and supervision	12,760 man-hr	4.50/man-hr	57,400	0.044
Utilities				
Water	2,720,800 M gal	0.04/M gal	108,800	0.083
Electricity	59,245,900 kwh	0.005/kwh[b]	296,200	0.226
Maintenance				
Labor and material			252,300	0.193
Analyses			30,000	0.023
Subtotal conversion costs			744,700	0.569
Subtotal direct costs			2,046,700	1.563
Indirect Costs				
Average capital charges at 14.5% of fixed investment			914,500	0.698
Overhead				
Plant, 20% of conversion costs			148,900	0.114
Administrative, 10% of operating labor			5,700	0.004
Subtotal indirect costs			1,069,100	0.816

	Cost/ton of ammonium sulfate, $	Total annual cost, $	Cost/ton of coal burned, $
Total annual operating costs for ammonium sulfate solution	13.984	3,115,800	2.379
Cost of air pollution control by alternate wet-limestone scrubbing process	8.612	1,918,900	1.465
Minimum expected transfer price of ammonium sulfate solution to fertilizer plant	5.372	1,196,900	0.914

[a] Basis:
Remaining life of power plant–35 years.
Coal burned–1,310,000 tons/yr–0.75 lb/kwh.
Stack gas reheat from 118° to 250° F., indirect liquid-gas method.
Power unit on-stream time–7,000 hr.
Midwest plant location–1969 costs.
Capital investment–$6,307,000 fixed; $445,000 working.

[b] Cost of electricity at power plant bus bar.

Table B-80. Economics for Power - Fertilizer Company Cooperative Venture Annual Manufacturing Costs for 19-14-0 Fertilizer Made with Ammonium Sulfate Solution Obtained by Scrubbing Power Plant Stack Gas[a]—Process C

(500-mw new power unit, 5.0% S in coal;
191,400 tons/yr fertilizer)

	Annual quantity	Unit cost, $	Total annual cost, $	$/ton of fertilizer
Direct Costs				
Delivered raw material				
Ammonia	11.6 M tons	35.00/ton	406,000	2.121
Phosphate rock	86.0 M tons	12.48/ton	1,073,300	5.608
Ammonium sulfate (solution at minimum transfer price)	222.8 M tons	5.37/ton	1,196,900	6.253
Conditioner	3.9 M tons	46.60/ton	181,700	0.949
Subtotal raw material			2,857,900	14.931
Conversion costs				
Operating labor and supervision	78,900 man-hr	4.50/man-hr	355,000	1.855
Utilities				
Net heat from boiler	1,210,100 MM Btu	0.40/MM Btu	484,000	2.529
Water	10,831,800 M gal	0.04/M gal	433,300	2.264
Electricity	62,164,900 kwh	0.005/kwh[b]	310,800	1.624
Maintenance				
Labor and material			559,600	2.924
Analyses			9,700	0.051
Subtotal conversion costs			2,152,400	11.247
Subtotal direct costs			5,010,300	26.178
Indirect Costs				
Depreciation at 10% of fixed investment			1,301,400	6.799
Local taxes and insurance at 2% of fixed investment			260,300	1.360
Overhead				
Plant, 20% of conversion costs			430,500	2.249
Administrative, research, and service, 10% of conversion costs			215,200	1.124
Subtotal indirect costs			2,207,400	11.532
Total annual manufacturing costs for 19-14-0 fertilizer			7,217,700	37.710

[a] Fertilizer plant on-stream time–7,000 hr/yr.
Midwest plant location–1969 costs.
Fertilizer capital investment–$13,014,300 fixed; $1,070,000 working.

[b] Cost of power and heat from power plant.

Table B-81. Economics for Power - Fertilizer Company Cooperative Venture
Average Annual Operating Costs for Scrubbing Power Plant Stack Gas
to Produce Ammonium Sulfate Solution[a]—Process C

(1000-mw new power unit, 3.5% S in coal;
301,560 tons ammonium sulfate/yr)

	Annual quantity	Unit cost, $	Total annual cost, $	Cost/ton of coal burned, $
Direct Costs				
Delivered raw material				
Ammonia	50.5 M tons	35.00/ton	1,768,500	0.697
Conversion costs				
Operating labor and supervision	15,080 man-hr	4.50/man-hr	67,900	0.027
Utilities				
Water	3,880,000 M gal	0.04/M gal	155,200	0.061
Electricity	95,522,000 kwh	0.004/kwh[b]	382,100	0.151
Maintenance				
Labor and material			372,500	0.147
Analyses			40,000	0.016
Subtotal conversion costs			1,017,700	0.402
Subtotal direct costs			2,786,200	1.099
Indirect Costs				
Average capital charges at 14.5% of fixed investment			1,350,400	0.532
Overhead				
Plant, 20% of conversion costs			203,500	0.080
Administrative, 10% of operating labor			6,800	0.003
Subtotal indirect costs			1,560,700	0.615

	Cost/ton of ammonium sulfate, $	Total annual cost, $	Cost/ton of coal burned, $
Total annual operating costs for ammonium sulfate solution	14.415	4,346,900	1.714
Cost of air pollution control by alternate wet-limestone scrubbing process	8.522	2,569,900	1.013
Minimum expected transfer price of ammonium sulfate solution to fertilizer plant	5.893	1,777,000	0.701

[a] Basis:
Remaining life of power plant—35 years.
Coal burned—2,537,300 tons/yr—0.725 lb/kwh.
Stack gas reheat from 118° to 250° F., indirect liquid-gas method.
Power unit on-stream time—7,000 hr.
Midwest plant location—1969 costs.
Capital investment—$9,313,000 fixed; $605,000 working.

[b] Cost of electricity at power plant bus bar.

Table B-82. Economics for Power - Fertilizer Company Cooperative Venture Annual Manufacturing Costs for 19-14-0 Fertilizer Made with Ammonium Sulfate Solution Obtained by Scrubbing Power Plant Stack Gas[a]—Process C

(1000-mw new power unit, 3.5% S in coal;
259,500 tons/yr fertilizer)

	Annual quantity	Unit cost, $	Total annual cost, $	$/ton of fertilizer
Direct Costs				
Delivered raw material				
Ammonia	15.7 M tons	35.00/ton	549,500	2.118
Phosphate rock	116.6 M tons	12.28/ton	1,431,800	5.518
Ammonium sulfate (solution at minimum transfer price)	301.6 M tons	5.89/ton	1,777,000	6.848
Conditioner	5.2 M tons	46.60/ton	242,300	0.934
Subtotal raw material			4,000,600	15.418
Conversion costs				
Operating labor and supervision	86,740 man-hr	4.50/man-hr	390,300	1.504
Utilities				
Net heat from boiler	1,694,000 MM Btu	0.30/MM Btu	508,200	1.958
Water	15,153,600 M gal	0.04/M gal	606,100	2.336
Electricity	85,732,500 kwh	0.004/kwh[b]	342,900	1.321
Maintenance				
Labor and material			689,700	2.658
Analyses			13,000	0.050
Subtotal conversion costs			2,550,200	9.827
Subtotal direct costs			6,550,800	25.245
Indirect Costs				
Depreciation at 10% of fixed investment			1,532,600	5.906
Local taxes and insurance at 2% of fixed investment			306,500	1.181
Overhead				
Plant, 20% of conversion costs			510,000	1.965
Administrative, research, and service, 10% of conversion costs			255,000	0.982
Subtotal indirect costs			2,604,100	10.036
Total annual manufacturing costs for 19-14-0 fertilizer			9,154,900	35.281

[a] Fertilizer plant on-stream time–7,000 hr/yr.
Midwest plant location–1969 costs.
Fertilizer capital investment–$15,326,300 fixed; $1,405,000 working.

[b] Cost of power and heat from power plant.

Table B-83. Economics for Power - Fertilizer Company Cooperative Venture Average Annual Operating Costs for Scrubbing Power Plant Stack Gas to Produce Ammonium Sulfate Solution[a]—Process C

(1000-mw existing power unit, 3.5% S in coal; 311,850 tons ammonium sulfate/yr)

	Annual quantity	Unit cost, $	Total annual cost, $	Cost/ton of coal burned, $
Direct Costs				
Delivered raw material				
Ammonia	52.2 M tons	35.00/ton	1,827,000	0.697
Conversion costs				
Operating labor and supervision	15,180 man-hr	4.50/man-hr	68,300	0.026
Utilities				
Water	3,880,000 M gal	0.05/M gal	194,000	0.074
Electricity	97,622,000 kwh	0.004/kwh[b]	390,500	0.149
Maintenance				
Labor and material			396,700	0.151
Analyses			40,000	0.015
Subtotal conversion costs			1,089,500	0.415
Subtotal direct costs			2,916,500	1.112
Indirect Costs				
Average capital charges at 14.8% of fixed investment			1,467,900	0.559
Overhead				
Plant, 20% of conversion costs			217,900	0.083
Administrative, 10% of operating labor			6,800	0.003
Subtotal indirect costs			1,692,600	0.645

	Cost/ton of ammonium sulfate, $	Total annual cost, $	Cost/ton of coal burned, $
Total annual operating costs for ammonium sulfate solution	14.780	4,609,100	1.757
Cost of air pollution control by alternate wet-limestone scrubbing process	8.765	2,733,400	1.041
Minimum expected transfer price of ammonium sulfate solution to fertilizer plant	6.015	1,875,700	0.716

[a] Basis:
Remaining life of power plant–32 years.
Coal burned–2,625,000 tons/yr–0.75 lb/kwh.
Stack gas reheat from 118° to 250° F., indirect liquid-gas method.
Power unit on-stream time–7,000 hr.
Midwest plant location–1969 costs.
Capital investment–$9,918,000 fixed; $640,000 working.

[b] Cost of electricity at power plant bus bar.

Table B-84. Economics for Power - Fertilizer Company Cooperative Venture Annual Manufacturing Costs for 19-14-0 Fertilizer Made with Ammonium Sulfate Solution Obtained by Scrubbing Power Plant Stack Gas[a]—Process C

(1000-mw existing power unit, 3.5% S in coal;
268,000 tons/yr fertilizer)

	Annual quantity	Unit cost, $	Total annual cost, $	$/ton of fertilizer
Direct Costs				
Delivered raw material				
Ammonia	16.2 M tons	35.00/ton	567,000	2.116
Phosphate rock	120.4 M tons	12.08/ton	1,454,400	5.427
Ammonium sulfate (solution at minimum transfer price)	311.9 M tons	6.01/ton	1,875,700	6.999
Conditioner	5.4 M tons	46.60/ton	251,600	0.939
Subtotal raw material			4,148,700	15.481
Conversion costs				
Operating labor and supervision	87,640 man-hr	4.50/man-hr	394,400	1.472
Utilities				
Net heat from boiler	1,642,000 MM Btu	0.45/MM Btu	738,900	2.757
Water	14,842,800 M gal	0.05/M gal	742,100	2.769
Electricity	84,154,000 kwh	0.004/kwh[b]	336,600	1.256
Maintenance				
Labor and material			752,800	2.809
Analyses			13,000	0.048
Subtotal conversion costs			2,977,800	11.111
Subtotal direct costs			7,126,500	26.592
Indirect Costs				
Depreciation at 10% of fixed investment			1,672,800	6.242
Local taxes and insurance at 2% of fixed investment			334,600	1.248
Overhead				
Plant, 20% of conversion costs			595,500	2.222
Administrative, research, and service, 10% of conversion costs			297,800	1.111
Subtotal indirect costs			2,900,700	10.823
Total annual manufacturing costs for 19-14-0 fertilizer			10,027,200	37.415

[a] Fertilizer plant on-stream time—7,000 hr/yr.
Midwest plant location—1969 costs.
Fertilizer capital investment—$16,728,400 fixed; $1,535,000 working.

[b] Cost of power and heat from power plant.

Table B-85. Power Company Economics - Total Venture Average Annual Manufacturing Costs for 28-14-0 Fertilizer Made with Ammonium Sulfate Solution Obtained by Scrubbing Power Plant Stack Gas[a]—Process A

(200-mw existing power unit, 3.5% S in coal;
128,600 tons/yr fertilizer)

	Annual quantity	Unit cost, $	Total annual cost, $	$/ton of fertilizer
Direct Costs				
Delivered raw material				
Ammonia	45.5 M tons	35.00/ton	1,592,200	12.385
Phosphate rock	60.9 M tons	12.88/ton	784,400	6.100
Conditioner	2.5 M tons	46.60/ton	117,900	0.917
Antifoam	48.8 M lb	0.20/lb	9,800	0.076
Nitric acid catalyst	243 troy oz	120/troy oz	28,900	0.225
Subtotal raw material			2,533,200	19.703
Conversion Costs				
Operating labor and supervision	70,000 man-hr	4.50/man-hr	315,000	2.449
Utilities				
Steam	471,200 M lb	0.60/M lb	282,700	2.198
Water	3,159,600 M gal	0.06/M gal	189,600	1.474
Electricity	36,617,000 kwh	0.006/kwh[b]	219,700	1.708
Maintenance				
Labor and material			564,400	4.389
Analyses			36,000	0.280
Subtotal conversion costs			1,607,400	12.498
Subtotal direct costs			4,140,600	32.201
Indirect Costs				
Average capital charges at 15.1% of fixed investment			1,890,500	14.701
Overhead				
Plant, 20% of conversion costs			321,500	2.500
Administrative, research, and service, 11% of conversion costs			176,800	1.375
Subtotal indirect costs			2,388,800	18.576

	Cost/ton of coal burned, $	Total annual cost, $	$/ton of fertilizer
Total annual manufacturing costs for 28-14-0 fertilizer	11.777	6,529,400	50.777

[a] Basis:
Remaining life of power plant–27 years.
Coal burned–554,400 tons/yr–0.792 lb/kwh.
Power unit operating stream time–7,000 hr/yr. Fertilizer plant on-stream time–7,000 hr/yr.
Stack gas reheat from 118° to 250° F., indirect liquid-gas method.
Midwest plant location–1969 costs.
Capital investment–$12,520,000 fixed; $875,000 working.

[b] Cost of electricity at power plant bus bar.

Table B-86. Power Company Economics - Total Venture Average Annual Manufacturing Costs for 28-14-0 Fertilizer Made with Ammonium Sulfate Solution Obtained by Scrubbing Power Plant Stack Gas[a]—Process A

(500-mw new power unit, 2.0% S in coal; 173,600 tons/yr fertilizer)

	Annual quantity	Unit cost, $	Total annual cost, $	$/ton of fertilizer
Direct Costs				
Delivered raw material				
Ammonia	61.4 M tons	35.00/ton	2,150,000	12.385
Phosphate rock	82.2 M tons	12.48/ton	1,025,900	5.910
Conditioner	3.4 M tons	46.60/ton	159,700	0.920
Antifoam	65.8 M lb	0.20/lb	13,600	0.076
Nitric acid catalyst	325 troy oz	120/troy oz	39,000	0.225
Subtotal raw material			3,388,200	19.516
Conversion costs				
Operating labor and supervision	76,000 man-hr	4.50/man-hr	342,000	1.970
Utilities				
Steam	640,290 M lb	0.40/M lb[b]	256,100	1.475
Water	4,279,000 M gal	0.05/M gal	214,000	1.232
Electricity	63,147,000 kwh	0.005/kwh[c]	315,700	1.819
Maintenance				
Labor and material			751,000	4.327
Analyses			43,000	0.248
Subtotal conversion costs			1,921,800	11.071
Subtotal direct costs			5,310,000	30.587
Indirect Costs				
Average capital charges at 14.5% of fixed investment			2,420,800	13.943
Overhead				
Plant, 20% of conversion costs			384,400	2.214
Administrative, research, and service, 11% of conversion costs			211,400	1.218
Subtotal indirect costs			3,016,600	17.375

	Cost/ton of coal burned, $	Total annual cost, $	$/ton of fertilizer
Total annual manufacturing costs for 28-14-0 fertilizer	6.356	8,326,600	47.962

[a] Basis:
Remaining life of power plant—35 years.
Coal burned—1,310,000 tons/yr—0.75 lb/kwh.
Power unit operating stream time—7,000 hr/yr. Fertilizer plant on-stream time—7,000 hr/yr.
Stack gas reheat from 118° to 250° F., indirect liquid-gas method.
Midwest plant location—1969 costs.
Capital investment—$16,695,000 fixed; $1,170,800 working.

[b] Cost of steam from power cycle.

[c] Cost of electricity at power plant bus bar.

Table B-87. Power Company Economics - Total Venture Average Annual Manufacturing Costs for 28-14-0 Fertilizer Made with Ammonium Sulfate Solution Obtained by Scrubbing Power Plant Stack Gas[a]—Process A

(500-mw new power unit, 3.5% S in coal;
303,800 tons/yr fertilizer)

	Annual quantity	Unit cost, $	Total annual cost, $	$/ton of fertilizer
Direct Costs				
Delivered raw material				
Ammonia	107.5 M tons	35.00/ton	3,762,500	12.385
Phosphate Rock	143.9 M tons	11.88/ton	1,709,500	5.627
Conditioner	6.0 M tons	46.60/ton	279,600	0.920
Antifoam	115.2 M lb	0.18/lb	20,700	0.068
Nitric acid catalyst	570 troy oz	120/troy oz	68,400	0.225
Subtotal raw material			5,840,700	19.225
Conversion costs				
Operating labor and supervision	98,000 man-hr	4.50/man-hr	441,000	1.452
Utilities				
Steam	1,112,000 M lb	0.40/M lb[b]	448,100	1.475
Water	7,350,000 M gal	0.05/M gal	367,500	1.210
Electricity	82,355,000 kwh	0.005/kwh[c]	411,800	1.355
Maintenance				
Labor and material			966,000	3.180
Analyses			75,000	0.247
Subtotal conversion costs			2,709,400	8.919
Subtotal direct costs			8,550,100	28.144
Indirect Costs				
Average capital charges at 14.5% of fixed investment			3,113,200	10.247
Overhead				
Plant, 20% of conversion costs			541,900	1.784
Administrative, research, and service, 11% of conversion costs			298,000	0.981
Subtotal indirect costs			3,953,100	13.012

	Cost/ton of coal burned, $	Total annual cost, $	$/ton of fertilizer
Total annual manufacturing costs for 28-14-0 fertilizer	9.544	12,503,200	41.156

[a] Basis:
Remaining life of power plant—35 years.
Coal burned—1,310,000 tons/yr—0.75 lb/kwh.
Power unit operating stream time—7,000 hr/yr. Fertilizer plant on-stream time—7,000 hr/yr.
Stack gas reheat from 118° to 250° F., indirect liquid-gas method.
Midwest plant location—1969 costs.
Capital investment—$21,470,000 fixed; $1,890,500 working.

[b] Cost of steam from power cycle.

[c] Cost of electricity at power plant bus bar.

Table B-88. Power Company Economics - Total Venture
Average Annual Manufacturing Costs for 28-14-0 Fertilizer Made with Ammonium Sulfate Solution Obtained by Scrubbing Power Plant Stack Gas[a]—Process A

(500-mw existing power unit, 3.5% S in coal;
310,800 tons/yr fertilizer)

	Annual quantity	Unit cost, $	Total annual cost, $	$/ton of fertilizer
Direct Costs				
Delivered raw material				
Ammonia	110.0 M tons	35.00/ton	3,850,000	12.387
Phosphate rock	147.2 M tons	11.88/ton	1,748,700	5.627
Conditioner	6.1 M tons	46.60/ton	284,300	0.915
Antifoam	117.8 M lb	0.18/lb	21,200	0.068
Nitric acid catalyst	583 troy oz	120/troy oz	70,000	0.225
Subtotal raw material			5,974,200	19.222
Conversion Costs				
Operating labor and supervision	98,500 man-hr	4.50/man-hr	443,300	1.426
Utilities				
Steam	1,137,600 M lb	0.50/M lb	568,800	1.830
Water	7,519,000 M gal	0.06/M gal	451,100	1.451
Electricity	83,405,000 kwh	0.005/kwh[b]	417,000	1.342
Maintenance				
Labor and material			1,000,000	3.218
Analyses			75,000	0.241
Subtotal conversion costs			2,955,200	9.508
Subtotal direct costs			8,929,400	28.730
Indirect Costs				
Average capital charges at 14.8% of fixed investment			3,303,400	10.629
Overhead				
Plant, 20% of conversion costs			591,000	1.901
Administrative, research, and service, 11% of conversion costs			325,100	1.046
Subtotal indirect costs			4,219,500	13.576

	Cost/ton of coal burned, $	Total annual cost, $	$/ton of fertilizer
Total annual manufacturing costs for 28-14-0 fertilizer	9.815	13,148,900	42.306

[a] Basis:
Remaining life of power plant–32 years.
Coal burned–1,339,600 tons/yr–0.767 lb/kwh.
Power unit operating stream time–7,000 hr/yr. Fertilizer plant on-stream time–7,000 hr/yr.
Stack gas reheat from 118° to 250° F., indirect liquid-gas method.
Midwest plant location–1969 costs.
Capital investment–$22,320,000 fixed; $1,937,700 working.

[b] Cost of electricity at power plant bus bar.

Table B-89. Power Company Economics - Total Venture Average Annual Manufacturing Costs for 28-14-0 Fertilizer Made with Ammonium Sulfate Solution Obtained by Scrubbing Power Plant Stack Gas[a]—Process A

(500-mw new power unit, 5.0% S in coal; 434,000 tons/yr fertilizer)

	Annual quantity	Unit cost, $	Total annual cost, $	$/ton of fertilizer
Direct Costs				
Delivered raw material				
Ammonia	153.9 M tons	30.00/ton	4,618,000	10.640
Phosphate rock	206.6 M tons	11.88/ton	2,442,100	5.627
Conditioner	8.6 M tons	46.60/ton	399,300	0.920
Antifoam	164.2 M lb	0.15/lb	24,600	0.057
Nitric acid catalyst	815 troy oz	120/troy oz	97,800	0.225
Subtotal raw material			7,581,800	17.469
Conversion costs				
Operating labor and supervision	118,000 man-hr	4.50/man-hr	531,000	1.223
Utilities				
Steam	1,670,000 M lb	0.40/M lb[b]	668,000	1.539
Water	9,943,000 M gal	0.04/M gal	397,700	0.916
Electricity	83,475,000 kwh	0.005/kwh[c]	417,400	0.962
Maintenance				
Labor and material			1,125,000	2.592
Analyses			90,000	0.208
Subtotal conversion costs			3,229,100	7.440
Subtotal direct costs			10,810,900	24.909
Indirect Costs				
Average capital charges at 14.5% of fixed investment			3,788,800	8.730
Overhead				
Plant, 20% of conversion costs			645,800	1.488
Administrative, research, and service, 11% of conversion costs			355,200	0.818
Subtotal indirect costs			4,789,800	11.036

	Cost/ton of coal burned, $	Total annual cost, $	$/ton of fertilizer
Total annual manufacturing costs for 28-14-0 fertilizer	11.909	15,600,700	35.945

[a] Basis:
Remaining life of power plant–35 years.
Coal burned–1,310,000 tons/yr–0.75 lb/kwh.
Power unit operating stream time–7,000 hr/yr. Fertilizer plant on-stream time–7,000 hr/yr.
Stack gas reheat from 118° to 250° F., indirect liquid-gas method.
Midwest plant location–1969 costs.
Capital investment–$26,130,000 fixed; $2,393,100 working.

[b] Cost of steam from power cycle.

[c] Cost of electricity at power plant bus bar.

Table B-90. Power Company Economics - Total Venture Average Annual Manufacturing Costs for 28-14-0 Fertilizer Made with Ammonium Sulfate Solution Obtained by Scrubbing Power Plant Stack Gas[a]—Process A

(1000-mw new power unit, 3.5% S in coal; 587,500 tons/yr fertilizer)

	Annual quantity	Unit cost, $	Total annual cost, $	$/ton of fertilizer
Direct Costs				
Delivered raw material				
Ammonia	208.4 M tons	30.00/ton	6,252,000	10.642
Phosphate rock	278.3 M tons	11.88/ton	3,306,200	5.627
Conditioner	11.5 M tons	46.60/ton	537,300	0.917
Antifoam	223.4 M lb	0.15/lb	33,500	0.057
Nitric acid catalyst	111.2 troy oz	120/troy oz	133,400	0.225
Subtotal raw material			10,262,400	17.468
Conversion costs				
Operating labor and supervision	135,000 man-hr	4.50/man-hr	607,500	1.034
Utilities				
Steam	2,276,000 M lb	0.30/M lb[b]	682,800	1.162
Water	12,137,000 M gal	0.04/M gal	485,500	0.826
Electricity	133,239,000 kwh	0.004/kwh[c]	533,000	0.907
Maintenance				
Labor and material			1,550,000	2.638
Analyses			120,000	0.204
Subtotal conversion costs			3,978,800	6.771
Subtotal direct costs			14,241,200	24.239
Indirect Costs				
Average capital charges at 14.5% of fixed investment			5,002,500	8.515
Overhead				
Plant, 20% of conversion costs			795,800	1.354
Administrative, research, and service, 11% of conversion costs			437,700	0.745
Subtotal indirect costs			6,236,000	10.614

	Cost/ton of coal burned, $	Total annual cost, $	$/ton of fertilizer
Total annual manufacturing costs for 28-14-0 fertilizer	8.070	20,477,200	34.853

[a] Basis:
Remaining life of power plant – 35 years.
Coal burned – 2,537,300 tons/yr – 0.725 lb/kwh.
Power unit operating stream time – 7,000 hr/yr. Fertilizer plant on-stream time – 7,000 hr/yr.
Stack gas reheat from 118° to 250° F., indirect liquid-gas method.
Midwest plant location – 1969 costs.
Capital investment – $34,500,000 fixed; $3,244,200 working.

[b] Cost of steam from power cycle.

[c] Cost of electricity at power plant bus bar.

Table B-91. Power Company Economics · Total Venture
Average Annual Manufacturing Costs for 28-14-0 Fertilizer Made with Ammonium Sulfate Solution Obtained by Scrubbing Power Plant Stack Gas[a]—Process A

(1000-mw existing power unit, 3.5% S in coal;
607,600 tons/yr fertilizer)

	Annual quantity	Unit cost, $	Total annual cost, $	$/ton of fertilizer
Direct Costs				
Delivered raw material				
Ammonia	215.5 M tons	30.00/ton	6,465,000	10.640
Phosphate rock	287.8 M tons	11.88/ton	3,419,000	5.627
Conditioner	12.0 M tons	46.60/ton	559,200	0.920
Antifoam	231.0 M lb	0.15/lb	34,700	0.057
Nitric acid catalyst	1150 troy oz	120/troy oz	137,000	0.225
Subtotal raw material			10,614,900	17.469
Conversion costs				
Operating labor and supervision	136,000 man-hr	4.50/man-hr	612,000	1.007
Utilities				
Steam	2,354,000 M lb	0.45/M lb	1,059,300	1.744
Water	12,551,000 M gal	0.05/M gal	627,600	1.033
Electricity	135,339,000 kwh	0.004/kwh[b]	541,300	0.891
Maintenance				
Labor and material			1,600,000	2.633
Analyses			120,000	0.197
Subtotal conversion costs			4,560,200	7.505
Subtotal direct costs			15,175,100	24.974
Indirect Costs				
Average capital charges at 14.8% of fixed investment			5,409,400	8.903
Overhead				
Plant, 20% of conversion costs			912,000	1.501
Administrative, research, and service, 11% of conversion costs			501,600	0.826
Subtotal indirect costs			6,823,000	11.230

	Cost/ton of coal burned, $	Total annual cost, $	$/ton of fertilizer
Total annual manufacturing costs for 28-14-0 fertilizer	8.380	21,998,100	36.204

[a] Basis:
Remaining life of power plant–32 years.
Coal burned–2,625,000 tons/yr–0.75 lb/kwh.
Power unit operating stream time–7,000 hr/yr. Fertilizer plant on-stream time–7,000 hr/yr.
Stack gas reheat from 118° to 250° F., indirect liquid-gas method.
Midwest plant location–1969 costs.
Capital investment–$36,550,000 fixed; $3,358,800 working.

[b] Cost of electricity at power plant bus bar.

Table B-92. Power Company Economics - Total Venture Average Annual Manufacturing Costs for 26-19-0 Fertilizer Made with Ammonium Sulfate Solution and Sulfur Dioxide Obtained by Scrubbing Power Plant Stack Gas[a]—Process B

(200-mw existing power unit, 3.5% S in coal; 97,100 tons/yr fertilizer)

	Annual quantity	Unit cost, $	Total annual cost, $	$/ton of fertilizer
Direct Costs				
Delivered raw material				
Ammonia	32.1 M tons	35.00/ton	1,124,400	11.580
Phosphate rock	59.8 M tons	12.88/ton	770,800	7.938
Conditioner	1.9 M tons	46.60/ton	90,500	0.932
Antifoam	48.00 M lb	0.20/lb	9,600	0.099
Nitric acid catalyst	160 troy oz	120/troy oz	19,200	0.198
Subtotal raw material			2,014,500	20.747
Conversion costs				
Operating labor and supervision	82,300 man-hr	4.50/man-hr	370,400	3.815
Utilities				
Steam	339,700 M lb	0.60/M lb	203,800	2.099
Water	1,918,300 M gal	0.06/M gal	115,100	1.185
Electricity	28,233,300 kwh	0.006/kwh[b]	169,400	1.745
Maintenance				
Labor and material			515,000	5.304
Analyses			28,000	0.288
Subtotal conversion costs			1,401,700	14.436
Subtotal direct costs			3,416,200	35.183
Indirect Costs				
Average capital charges at 15.1% of initial fixed investment			1,725,600	17.772
Overhead				
Plant, 20% of conversion costs			280,300	2.887
Administrative, research, and service, 11% of conversion costs			154,200	1.588
Subtotal indirect costs			2,160,100	22.247
		Cost/ton of coal burned, $	Total annual cost, $	$/ton of fertilizer
Total annual manufacturing costs for 26-19-0 fertilizer		10.058	5,576,300	57.430

[a] Basis:

Remaining life of power plant—27 years.
Coal burned—554,400 tons/yr—0.792 lb/kwh.
Stack gas reheat from 118° to 250° F., indirect liquid-gas method.
Power unit on-stream time—7,000 hr. Fertilizer plant on-stream time—7,000 hr.
Midwest plant location—1969 costs.
Capital investment—$11,428,000 fixed; $875,000 working.

[b] Cost of electricity at power plant bus bar.

Table B-93. Power Company Economics - Total Venture
Average Annual Manufacturing Costs for 26-19-0 Fertilizer Made with Ammonium Sulfate Solution and Sulfur Dioxide Obtained by Scrubbing Power Plant Stack Gas[a]—Process B

(500-mw new power unit, 2.0% S in coal;
131,300 tons/yr fertilizer)

	Annual quantity	Unit cost, $	Total annual cost, $	$/ton of fertilizer
Direct Costs				
Delivered raw material				
Ammonia	43.4 M tons	35.00/ton	1,520,500	11.580
Phosphate rock	81.0 M tons	12.48/ton	1,010,900	7.699
Conditioner	2.6 M tons	46.60/ton	122,400	0.932
Antifoam	65.0 M lb	0.20/lb	13,000	0.099
Nitric acid catalyst	216 troy oz	120/troy oz	25,900	0.197
Subtotal raw material			2,692,700	20.507
Conversion costs				
Operating labor and supervision	87,700 man-hr	4.50/man-hr	394,600	3.005
Utilities				
Steam	462,770 M lb	0.40/M lb[b]	185,100	1.410
Water	2,629,620 M gal	0.05/M gal	131,500	1.002
Electricity	50,221,500 kwh	0.005/kwh[c]	251,100	1.912
Maintenance				
Labor and material			690,000	5.255
Analyses			40,000	0.304
Subtotal conversion costs			1,692,300	12.888
Subtotal direct costs			4,385,000	33.395
Indirect Costs				
Average capital charges at 14.5% of initial fixed investment			2,258,200	17.198
Overhead				
Plant, 20% of conversion costs			338,500	2.578
Administrative, research, and service, 11% of conversion costs			186,200	1.418
Subtotal indirect costs			2,782,900	21.194
		Cost/ton of coal burned, $	Total annual cost, $	$/ton of fertilizer
Total annual manufacturing costs for 26-19-0 fertilizer		5.472	7,167,900	54.589

[a] Basis:
Remaining life of power plant–35 years.
Coal burned–1,310,000 tons/yr–0.75 lb/kwh.
Stack gas reheat from 118° to 250° F., indirect liquid-gas method.
Power unit on-stream time–7,000 hr. Fertilizer plant on-stream time–7,000 hr.
Midwest plant location–1969 costs.
Capital investment–$15,574,000 fixed; $1,170,800 working.

[b] Cost of steam from power plant cycle.

[c] Cost of electricity at power plant bus bar.

Table B-94. Power Company Economics - Total Venture Average Annual Manufacturing Costs for 26-19-0 Fertilizer Made with Ammonium Sulfate Solution and Sulfur Dioxide Obtained by Scrubbing Power Plant Stack Gas[a]—Process B

(500-mw new power unit, 3.5% S in coal; 230,000 tons/yr fertilizer)

	Annual quantity	Unit cost, $	Total annual cost, $	$/ton of fertilizer
Direct Costs				
Delivered raw material				
Ammonia	76.1 M tons	35.00/ton	2,663,500	11.580
Phosphate rock	141.8 M tons	11.88/ton	1,684,600	7.324
Conditioner	4.6 M tons	46.60/ton	214,400	0.932
Antifoam	113.4 M lb	0.18/lb	20,400	0.089
Nitric acid catalyst	377 troy oz	120/troy oz	45,200	0.197
Subtotal raw material			4,628,100	20.122
Conversion costs				
Operating labor and supervision	101,980 man-hr	4.50/man-hr	458,900	2.000
Utilities				
Steam	805,070 M lb	0.40/M lb[b]	322,000	1.400
Water	4,479,300 M gal	0.05/M gal	224,000	0.974
Electricity	61,293,750 kwh	0.005/kwh[c]	306,500	1.332
Maintenance				
Labor and material			881,000	3.830
Analyses			65,000	0.282
Subtotal conversion costs			2,257,400	9.818
Subtotal direct costs			6,885,500	29.940
Indirect Costs				
Average capital charges at 14.5% of initial fixed investment			1,899,500	8.258
Overhead				
Plant, 20% of conversion costs			451,500	1.963
Administrative, research, and service, 11% of conversion costs			248,300	1.079
Subtotal indirect costs			2,599,300	11.300

	Cost/ton of coal burned, $	Total annual cost, $	$/ton of fertilizer
Total annual manufacturing costs for 26-19-0 fertilizer	7.240	9,484,800	41.240

[a] Basis:
Remaining life of power plant–35 years.
Coal burned–1,310,000 tons/yr–0.75 lb/kwh.
Stack gas reheat from 118° to 250° F., indirect liquid-gas method.
Power unit on-stream time–7,000 hr. Fertilizer plant on-stream time–7,000 hr.
Midwest plant location–1969 costs.
Capital investment–$19,689,000 fixed; $1,890,500 working.

[b] Cost of steam from power plant bus bar.

[c] Cost of electricity at power plant bus bar.

Table B-95. Power Company Economics - Total Venture Average Annual Manufacturing Costs for 26-19-0 Fertilizer Made with Ammonium Sulfate Solution and Sulfur Dioxide Obtained by Scrubbing Power Plant Stack Gas[a]—Process B

(500-mw existing power unit, 3.5% S in coal;
235,800 tons/yr fertilizer)

	Annual quantity	Unit cost, $	Total annual cost, $	$/ton of fertilizer
Direct Costs				
Delivered raw material				
Ammonia	78.0 M tons	35.00/ton	2,730,600	11.580
Phosphate rock	145.4 M tons	11.88/ton	1,727,000	7.324
Conditioner	4.7 M tons	46.60/ton	219,800	0.932
Antifoam	116.7 M lb	0.18/lb	21,000	0.089
Nitric acid catalyst	385 troy oz	120/troy oz	46,200	0.197
Subtotal raw material			4,744,600	20.122
Conversion costs				
Operating labor and supervision	102,440 man-hr	4.50/man-hr	461,000	1.955
Utilities				
Steam	825,400 M lb	0.50/M lb	412,700	1.750
Water	4,598,300 M gal	0.06/M gal	275,900	1.170
Electricity	63,660,000 kwh	0.005/kwh[b]	318,300	1.350
Maintenance				
Labor and material			902,000	3.825
Analyses			65,000	0.276
Subtotal conversion costs			2,434,900	10.326
Subtotal direct costs			7,179,500	30.448
Indirect Costs				
Average capital charges at 14.8% of initial fixed investment			2,988,300	12.673
Overhead				
Plant, 20% of conversion costs			487,000	2.065
Administrative, research, and service, 11% of conversion costs			267,800	1.136
Subtotal indirect costs			3,743,100	15.874
		Cost/ton of coal burned, $	Total annual cost, $	$/ton of fertilizer
Total annual manufacturing costs for 26-19-0 fertilizer		8.154	10,922,600	46.322

[a] Basis:
Remaining life of power plant—32 years.
Coal burned—1,339,600 tons/yr—0.767 lb/kwh.
Stack gas reheat from 118° to 250° F., indirect liquid-gas method.
Power unit on-stream time—7,000 hr. Fertilizer plant on-stream time—7,000 hr.
Midwest plant location—1969 costs.
Capital investment—$20,191,000 fixed; $1,937,700 working.

[b] Cost of electricity at power plant bus bar.

Table B-96. Power Company Economics - Total Venture
Average Annual Manufacturing Costs for 26-19-0 Fertilizer Made with Ammonium Sulfate Solution and Sulfur Dioxide Obtained by Scrubbing Power Plant Stack Gas[a]—Process B

(500-mw new power unit, 5.0% S in coal;
328,600 tons/yr fertilizer)

	Annual quantity	Unit cost, $	Total annual cost, $	$/ton of fertilizer
Direct Costs				
Delivered raw material				
Ammonia	108.7 M tons	30.00/ton	3,261,700	9.926
Phosphate rock	202.6 M tons	11.88/ton	2,406,700	7.324
Conditioner	6.6 M tons	46.60/ton	306,300	0.932
Antifoam	161.7 M lb	0.15/lb	24,300	0.074
Nitric acid catalyst	540 troy oz	120/troy oz	64,800	0.197
Subtotal raw material			6,063,800	18.453
Conversion costs				
Operating labor and supervision	117,500 man-hr	4.50/man-hr	528,700	1.609
Utilities				
Steam	1,148,000 M lb	0.40/M lb[b]	459,200	1.397
Water	6,726,720 M gal	0.04/M gal	269,100	0.819
Electricity	73,720,500 kwh	0.005/kwh[c]	368,600	1.122
Maintenance				
Labor and material			1,058,000	3.220
Analyses			90,000	0.274
Subtotal conversion costs			2,773,600	8.441
Subtotal direct costs			8,837,400	26.894
Indirect Costs				
Average capital charges at 14.5% of initial fixed investment			3,411,100	10.381
Overhead				
Plant, 20% of conversion costs			554,700	1.688
Administrative, research, and service, 11% of conversion costs			305,100	0.928
Subtotal indirect costs			4,270,900	12.997
		Cost/ton of coal burned, $	Total annual cost, $	$/ton of fertilizer
Total annual manufacturing costs for 26-19-0 fertilizer		10.006	13,108,300	39.891

[a] Basis:
Remaining life of power plant – 35 years.
Coal burned – 1,310,000 tons/yr – 0.75 lb/kwh.
Stack gas reheat from 118° to 250° F., indirect liquid-gas method.
Power unit on-stream time – 7,000 hr. Fertilizer plant on-stream time – 7,000 hr.
Midwest plant location – 1969 costs.
Capital investment – $23,525,000 fixed; $2,393,100 working.

[b] Cost of steam from power plant cycle.

[c] Cost of electricity at power plant bus bar.

Table B-97. Power Company Economics - Total Venture
Average Annual Manufacturing Costs for 26-19-0 Fertilizer Made with Ammonium Sulfate Solution and Sulfur Dioxide Obtained by Scrubbing Power Plant Stack Gas[a]—Process B

(1000-mw new power unit, 3.5% S in coal;
444,000 tons/yr fertilizer)

	Annual quantity	Unit cost, $	Total annual cost, $	$/ton of fertilizer
Direct Costs				
Delivered raw material				
Ammonia	146.9 M tons	30.00/ton	4,407,100	9.926
Phosphate rock	273.7 M tons	11.88/ton	3,251,900	7.324
Conditioner	8.9 M tons	46.60/ton	413,800	0.932
Antifoam	219.3 M lb	0.15/lb	32,900	0.074
Nitric acid catalyst	733 troy oz	120/troy oz	87,900	0.198
Subtotal raw material			8,193,600	18.454
Conversion costs				
Operating labor and supervision	136,700 man-hr	4.50/man-hr	615,200	1.386
Utilities				
Steam	1,678,300 M lb	0.30/M lb[b]	503,500	1.134
Water	8,680,000 M gal	0.04/M gal	347,200	0.782
Electricity	99,575,000 kwh	0.004/kwh[c]	398,300	0.897
Maintenance				
Labor and material			1,375,000	3.097
Analyses			120,000	0.270
Subtotal conversion costs			3,359,200	7.566
Subtotal direct costs			11,552,800	26.020
Indirect Costs				
Average capital charges at 14.5% of initial fixed investment			4,495,000	10.124
Overhead				
Plant, 20% of conversion costs			671,800	1.513
Administrative, research, and service, 11% of conversion costs			369,500	0.832
Subtotal indirect costs			5,536,300	12.469

	Cost/ton of coal burned, $	Total annual cost, $	$/ton of fertilizer
Total annual manufacturing costs for 26-19-0 fertilizer	6.735	17,089,100	38.489

[a] Basis:
Remaining life of power plant—35 years.
Coal burned—2,537,300 tons/yr—0.725 lb/kwh.
Stack gas reheat from 118° to 250° F., indirect liquid-gas method.
Power unit on-stream time—7,000 hr. Fertilizer plant on-stream time—7,000 hr.
Midwest plant location—1969 costs.
Capital investment—$31,000,000 fixed; $3,244,200 working.

[b] Cost of steam from power plant cycle.

[c] Cost of electricity at power plant bus bar.

Table B-98. Power Company Economics - Total Venture Average Annual Manufacturing Costs for 26-19-0 Fertilizer Made with Ammonium Sulfate Solution and Sulfur Dioxide Obtained by Scrubbing Power Plant Stack Gas[a]—Process B

(1000-mw existing power unit, 3.5% S in coal; 460,000 tons/yr fertilizer)

	Annual quantity	Unit cost, $	Total annual cost, $	$/ton of fertilizer
Direct Costs				
Delivered raw material				
Ammonia	152.2 M tons	30.00/ton	4,566,000	9.926
Phosphate rock	283.6 M tons	11.88/ton	3,369,200	7.324
Conditioner	9.2 M tons	46.60/ton	428,700	0.932
Antifoam	226.8 M lb	0.15/lb	34,000	0.074
Nitric acid catalyst	760 troy oz	120/troy oz	91,200	0.198
Subtotal raw material			8,489,100	18.454
Conversion costs				
Operating labor and supervision	137,700 man-hr	4.50/man-hr	619,600	1.347
Utilities				
Steam	1,739,500 M lb	0.45/M lb	782,800	1.702
Water	8,988,000 M gal	0.05/M gal	449,400	0.977
Electricity	104,941,250 kwh	0.004/kwh[b]	419,800	0.912
Maintenance				
Labor and material			1,463,000	3.180
Analyses			120,000	0.261
Subtotal conversion costs			3,854,600	8.379
Subtotal direct costs			12,343,700	26.833
Indirect Costs				
Average capital charges at 14.8% of initial fixed investment			4,869,800	10.586
Overhead				
Plant, 20% of conversion costs			770,900	1.676
Administrative, research, and service, 11% of conversion costs			424,000	0.921
Subtotal indirect costs			6,064,700	13.183

	Cost/ton of coal burned, $	Total annual cost, $	$/ton of fertilizer
Total annual manufacturing costs for 26-19-0 fertilizer	7.013	18,408,400	40.016

[a] Basis:
Remaining life of power plant – 32 years.
Coal burned – 2,625,000 tons/yr – 0.75 lb/kwh.
Stack gas reheat from 118° to 250° F., indirect liquid-gas method.
Power unit on-stream time – 7,000 hr. Fertilizer plant on-stream time – 7,000 hr.
Midwest plant location – 1969 costs.
Capital investment – $32,904,000 fixed; $3,358,800 working.

[b] Cost of electricity at power plant bus bar.

Table B-99. Power Company Economics - Total Venture
Average Annual Manufacturing Costs for 19-14-0 Fertilizer Made with Ammonium Sulfate Solution Obtained by Scrubbing Power Plant Stack Gas[a]—Process C

*(200-mw existing power unit, 3.5% S in coal;
56,700 tons/yr fertilizer)*

	Annual quantity	Unit cost, $	Total annual cost, $	$/ton of fertilizer
Direct Costs				
Delivered raw material				
Ammonia	14.4 M tons	35.00/ton	505,400	8.914
Phosphate rock	25.5 M tons	13.88/ton	343,900	6.065
Conditioner	1.1 M tons	46.60/ton	51,300	0.905
Subtotal raw material			900,600	15.884
Conversion costs				
Operating labor and supervision	69,770 man-hr	4.50/man-hr	314,000	5.538
Utilities				
Net heat from boiler	358,400 MM Btu	0.60/MM Btu[b]	215,000	3.792
Water	3,930,400 M gal	0.06/M gal	235,900	4.160
Electricity	38,776,500 kwh	0.006/kwh[b]	232,700	4.104
Maintenance				
Labor and material			417,100	7.356
Analyses			15,900	0.280
Subtotal conversion costs			1,430,600	25.230
Subtotal direct costs			2,331,200	41.114
Indirect Costs				
Levelized capital charges at 15.1% of fixed investment			1,448,000	25.538
Overhead				
Plant, 20% of conversion costs			286,100	5.046
Administrative, research, and service, 11% of conversion costs			157,400	2.776
Subtotal indirect costs			1,891,500	33.360
		Cost/ton of coal burned, $	Total annual cost, $	$/ton of fertilizer
Total annual manufacturing costs for 19-14-0 fertilizer		7.617	4,222,700	74.474

[a] Basis:
Remaining life of power plant—27 years.
Coal burned—554,400 tons/yr—0.75 lb/kwh.
Stack gas reheat from 118° to 250° F., indirect liquid-gas method.
Power unit on-stream time—7,000 hr. Fertilizer plant on-stream time—7,000 hr.
Midwest plant location—1969 costs.
Capital investment—$9,589,500 fixed; $606,000 working.

[b] Cost of electricity at power plant bus bar and heat from boiler exhaust gas at 1000° F.

Table B-100. Power Company Economics - Total Venture Average Annual Manufacturing Costs for 19-14-0 Fertilizer Made with Ammonium Sulfate Solution Obtained by Scrubbing Power Plant Stack Gas[a]—Process C

(500-mw new power unit, 2.0% S in coal;
76,600 tons/yr fertilizer)

	Annual quantity	Unit cost, $	Total annual cost, $	$/ton of fertilizer
Direct Costs				
Delivered raw material				
Ammonia	19.5 M tons	35.00/ton	682,400	8.909
Phosphate rock	34.4 M tons	13.88/ton	477,500	6.234
Conditioner	1.5 M tons	46.60/ton	69,900	0.913
Subtotal raw material			1,229,800	16.056
Conversion costs				
Operating labor and supervision	73,720 man-hr	4.50/man-hr	331,700	4.330
Utilities				
Net heat from boiler	484,000 MM Btu	0.40/MM Btu[b]	193,600	2.527
Water	5,503,700 M gal	0.05/M gal	275,100	3.591
Electricity	68,061,000 kwh	0.005/kwh[b]	340,300	4.443
Maintenance				
Labor and material			560,000	7.311
Analyses			19,000	0.248
Subtotal conversion costs			1,719,700	22.450
Subtotal direct costs			2,949,500	38.506
Indirect Costs				
Levelized capital charges at 14.5% of fixed investment			1,893,300	24.717
Overhead				
Plant, 20% of conversion costs			343,900	4.489
Administrative, research, and service, 11% of conversion costs			189,200	2.470
Subtotal indirect costs			2,426,400	31.676

	Cost/ton of coal burned, $	Total annual cost, $	$/ton of fertilizer
Total annual manufacturing costs for 19-14-0 fertilizer	4.104	5,375,900	70.182

[a] Basis:
Remaining life of power plant—35 years.
Coal burned—1,310,000 tons/yr—0.75 lb/kwh.
Stack gas reheat from 118° to 250° F., indirect liquid-gas method.
Power unit on-stream time—7,000 hr. Fertilizer plant on-stream time—7,000 hr.
Midwest plant location—1969 costs.
Capital investment—$13,057,300 fixed; $780,000 working.

[b] Cost of electricity at power plant bus bar and heat from boiler exhaust gas at 1000° F.

Table B-101. Power Company Economics - Total Venture Average Annual Manufacturing Costs for 19-14-0 Fertilizer Made with Ammonium Sulfate Solution Obtained by Scrubbing Power Plant Stack Gas[a]—Process C

(500-mw new power unit, 3.5% S in coal;
134,000 tons/yr fertilizer)

	Annual quantity	Unit cost, $	Total annual cost, $	$/ton of fertilizer
Direct Costs				
Delivered raw material				
Ammonia	34.2 M tons	35.00/ton	1,197,000	8.933
Phosphate rock	60.2 M tons	12.68/ton	763,300	5.696
Conditioner	2.7 M tons	46.60/ton	125,000	0.939
Subtotal raw material			2,086,100	15.568
Conversion costs				
Operating labor and supervision	82,580 man-hr	4.50/man-hr	371,600	2.773
Utilities				
Net heat from boiler	847,000 MM Btu	0.40/MM Btu[b]	338,800	2.528
Water	9,516,800 M gal	0.05/M gal	475,800	3.551
Electricity	92,481,900 kwh	0.005/kwh[b]	462,400	3.451
Maintenance				
Labor and material			706,300	5.271
Analyses			33,100	0.247
Subtotal conversion costs			2,388,000	17.821
Subtotal direct costs			4,474,100	33.389
Indirect Costs				
Levelized capital charges at 14.5% of fixed investment			2,371,700	17.699
Overhead				
Plant, 20% of conversion costs			477,600	3.564
Administrative, research, and service, 11% of conversion costs			262,700	1.960
Subtotal indirect costs			3,112,000	23.223

	Cost/ton of coal burned, $	Total annual cost, $	$/ton of fertilizer
Total annual manufacturing costs for 19-14-0 fertilizer	5.791	7,586,100	56.612

[a] Basis:
Remaining life of power plant–35 years.
Coal burned–1,310,000 tons/yr–0.75 lb/kwh.
Stack gas reheat from 118° to 250° F., indirect liquid-gas method.
Power unit on-stream time–7,000 hr. Fertilizer plant on-stream time–7,000 hr.
Midwest plant location–1969 costs.
Capital investment–$16,356,800 fixed; $1,185,000 working.

[b] Cost of electricity at power plant bus bar and heat from boiler exhaust gas at 1000° F.

Table B-102. Power Company Economics - Total Venture Average Annual Manufacturing Costs for 19-14-0 Fertilizer Made with Ammonium Sulfate Solution Obtained by Scrubbing Power Plant Stack Gas[a]—Process C

(500-mw existing power unit, 3.5% S in coal; 137,000 tons/yr fertilizer)

	Annual quantity	Unit cost, $	Total annual cost, $	$/ton fertilizer
Direct Costs				
Delivered raw material				
Ammonia	35.0 M tons	35.00/ton	1,224,200	8.936
Phosphate rock	61.5 M tons	12.68/ton	779,800	5.692
Conditioner	2.8 M tons	46.60/ton	130,500	0.953
Subtotal raw material			2,134,500	15.581
Conversion costs				
Operating labor and supervision	83,080 man-hr	4.50/man-hr	373,900	2.729
Utilities				
Net heat from boiler	866,000 MM Btu	0.50/MM Btu[b]	433,000	3.161
Water	9,634,400 M gal	0.06/M gal	578,100	4.220
Electricity	94,056,900 kwh	0.005/kwh[b]	470,300	3.433
Maintenance				
Labor and material			748,500	5.463
Analyses			33,100	0.241
Subtotal conversion costs			2,636,900	19.247
Subtotal direct costs			4,771,400	34.828
Indirect Costs				
Levelized capital charges at 14.8% of fixed investment			2,564,800	18.721
Overhead				
Plant, 20% of conversion costs			527,400	3.850
Administrative, research, and service, 11% of conversion costs			290,100	2.117
Subtotal indirect costs			3,382,300	24.688
		Cost/ton of coal burned, $	Total annual cost, $	$/ton of fertilizer
Total annual manufacturing costs for 19-14-0 fertilizer		6.087	8,153,700	59.516

[a] Basis:

Remaining life of power plant—32 years.

Coal burned—1,339,600 tons/yr—0.75 lb/kwh.

Stack gas reheat from 118° to 250° F., indirect liquid-gas method.

Power unit on-stream time—7,000 hr. Fertilizer plant on-stream time—7,000 hr.

Midwest plant location—1969 costs.

Capital investment—$17,329,600 fixed; $1,260,000 working.

[b] Cost of electricity at power plant bus bar and heat from boiler exhaust gas at 1000° F.

Table B-103. Power Company Economics - Total Venture Average Annual Manufacturing Costs for 19-14-0 Fertilizer Made with Ammonium Sulfate Solution Obtained by Scrubbing Power Plant Stack Gas[a]—Process C

(500-mw new power unit, 5.0% S in coal; 191,400 tons/yr fertilizer)

	Annual quantity	Unit cost, $	Total annual cost, $	$/ton of fertilizer
Direct Costs				
Delivered raw material				
Ammonia	48.8 M tons	35.00/ton	1,708,000	8.924
Phosphate rock	86.0 M tons	12.48/ton	1,073,300	5.608
Conditioner	3.9 M tons	46.60/ton	181,700	0.949
Subtotal raw material			2,963,000	15.481
Conversion costs				
Operating labor and supervision	91,660 man-hr	4.50/man-hr	412,500	2.155
Utilities				
Net heat from boiler	1,210,100 MM Btu	0.40/MM Btu[b]	484,000	2.529
Water	13,552,600 M gal	0.04/M gal	542,100	2.832
Electricity	121,410,800 kwh	0.005/kwh[b]	607,000	3.171
Maintenance				
Labor and material			811,900	3.960
Analyses			39,700	0.207
Subtotal conversion costs			2,897,200	15.136
Subtotal direct costs			5,860,200	30.617
Indirect Costs				
Levelized capital charges at 14.5% of fixed investment			2,801,600	14.637
Overhead				
Plant, 20% of conversion costs			579,400	3.027
Administrative, research, and service, 11% of conversion costs			318,700	1.665
Subtotal indirect costs			3,699,700	19.329
		Cost/ton of coal burned, $	Total annual cost, $	$/ton of fertilizer
Total annual manufacturing costs for 19-14-0 fertilizer		7.298	9,559,900	49.946

[a] Basis:
Remaining life of power plant—35 years.
Coal burned—1,310,000 tons/yr—0.75 lb/kwh.
Stack gas reheat from 118° to 250° F., indirect liquid-gas method.
Power unit on-stream time—7,000 hr. Fertilizer plant on-stream time—7,000 hr.
Midwest plant location—1969 costs.
Capital investment—$19,321,300 fixed; $1,515,000 working.

[b] Cost of electricity at power plant bus bar and heat from boiler exhaust gas at 1000° F.

Table B-104. Power Company Economics - Total Venture Average Annual Manufacturing Costs for 19-14-0 Fertilizer Made with Ammonium Sulfate Solution Obtained by Scrubbing Power Plant Stack Gas[a]—Process C

(1000-mw new power unit, 3.5% S in coal; 259,500 tons/yr fertilizer)

	Annual quantity	Unit cost, $	Total annual cost, $	$/ton of fertilizer
Direct Costs				
Delivered raw material				
Ammonia	66.2 M tons	35.00/ton	2,318,000	8.933
Phosphate rock	116.6 M tons	12.28/ton	1,431,800	5.518
Conditioner	5.2 M tons	46.68/ton	242,300	0.934
Subtotal raw material			3,992,100	15.385
Conversion costs				
Operating labor ad supervision	101,820 man-hr	4.50/man-hr	458,200	1.766
Utilities				
Net heat from boiler	1,694,000 MM Btu	0.30/MM Btu[b]	508,200	1.958
Water	19,033,600 M gal	0.04/M gal	761,300	2.934
Electricity	181,254,500 kwh	0.004/kwh[b]	988,200	3.808
Maintenance				
Labor and material			1,062,200	4.093
Analyses			53,000	0.204
Subtotal conversion costs			3,831,100	14.763
Subtotal direct costs			7,823,200	30.148
Indirect Costs				
Levelized capital charges at 14.5% of fixed investment			3,572,700	13.767
Overhead				
Plant, 20% of conversion costs			766,200	2.952
Administrative, research, and service, 11% of conversion costs			421,400	1.624
Subtotal indirect costs			4,760,300	18.343

	Cost/ton of coal burned, $	Total annual cost, $	$/ton of fertilizer
Total annual manufacturing costs for 19-14-0 fertilizer	4.959	12,583,500	48.491

[a] Basis:
Remaining life of power plant–35 years.
Coal burned–2,537,300 tons/yr–0.75 lb/kwh.
Stack gas reheat from 118° to 250° F., indirect liquid-gas method.
Power unit on-stream time–7,000 hr. Fertilizer plant on-stream time–7,000 hr.
Midwest plant location–1969 costs.
Capital investment–$24,639,300 fixed; $2,010,000 working.

[b] Cost of electricity at power plant bus bar and heat form boiler exhaust gas at 1000° F.

Table B-105. Power Company Economics - Total Venture Average Annual Manufacturing Costs for 19-14-0 Fertilizer Made with Ammonium Sulfate Solution Obtained by Scrubbing Power Plant Stack Gas[a]—Process C

(1000-mw existing power unit, 3.5% S in coal; 268,000 tons/yr fertilizer)

	Annual quantity	Unit cost, $	Total annual cost, $	$/ton of fertilizer
Direct Costs				
Delivered raw material				
Ammonia	68.4 M tons	35.00/ton	2,394,000	8.933
Phosphate rock	120.4 M tons	12.08/ton	1,454,400	5.427
Conditioner	5.4 M tons	46.60/ton	251,600	0.939
Subtotal raw material			4,100,000	15.299
Conversion costs				
Operating labor and supervision	102,820 man-hr	4.50/man-hr	462,700	1.726
Utilities				
Net heat from boiler	1,642,000 MM Btu	0.45/MM Btu[b]	738,900	2.757
Water	18,722,800 M gal	0.05/M gal	936,100	3.493
Electricity	181,776,000 kwh	0.004/kwh[b]	727,100	2.713
Maintenance				
Labor and material			1,149,500	4.289
Analyses			52,900	0.197
Subtotal conversion costs			4,067,200	15.175
Subtotal direct costs			8,167,200	30.474
Indirect Costs				
Levelized capital charges at 14.8% of fixed investment			3,943,700	14.715
Overhead				
Plant, 20% of conversion costs			813,400	3.035
Administrative, research, and service, 11% of conversion costs			447,400	1.669
Subtotal indirect costs			5,204,500	19.419
		Cost/ton of coal burned, $	Total annual cost, $	$/ton of fertilizer
Total annual manufacturing costs for 19-14-0 fertilizer		5.094	13,371,700	49.893

[a] Basis:
Remaining life of power plant – 32 years.
Coal burned – 2,625,000 tons/yr – 0.75 lb/kwh.
Stack gas reheat from 118° to 250° F., indirect liquid-gas method.
Power unit on-stream time – 7,000 hr. Fertilizer plant on-stream time – 7,000 hr.
Midwest plant location – 1969 costs.
Capital investment – $26,646,400 fixed; $2,175,000 working.

[b] Cost of electricity at power plant bus bar and heat from boiler exhaust gas at 1000° F.

Table B-106

PROCESS A, NONREGULATED FERTILIZER CO. ECONOMICS, 200 MW., EXISTING UNIT, 3.5% S IN COAL, 28-14-0 FERTILIZER PRODUCTION

FIXED INVESTMENT = $ 12520000
TOTAL INITIAL INVESTMENT = $ 13395000
OVERALL INTEREST RATE OF RETURN WITH PAYMENT = 1.5%
OVERALL INTEREST RATE OF RETURN WITHOUT PAYMENT = NEG

YEARS REQUIRED FOR PAYOUT WITH PAYMENT: 11.4
NO PAYOUT WITHOUT PAYMENT

YEARS AFTER POWER UNIT START	ANNUAL OPERATION KW-HR/KW	TONS/YEAR FERTILIZER	TOTAL FERTILIZER MFG. COST, $/YEAR	ALTERNATIVE WET-LIMESTONE PROCESS COST AS PAYMENT TO FERTILIZER COMPANY FOR AIR POLLUTION CONTROL, $/YEAR	NET FERTILIZER MFG COST, $/YEAR		NET FERTILIZER SALES REVENUE, $/YEAR	GROSS INCOME, $/YEAR		NET INCOME AFTER TAXES, $/YEAR		CASH FLOW, $/YEAR		CUMULATIVE CASH FLOW, $		ANNUAL RETURN ON INITIAL INVESTMENT, %	
					WITH PAYMENT	WITHOUT PAYMENT		WITH PAYMENT	WITHOUT PAYMENT	WITH PAYMENT	WITHOUT PAYMENT	WITH PAYMENT	WITHOUT PAYMENT	WITH PAYMENT	WITHOUT PAYMENT	WITH PAYMENT	WITHOUT PAYMENT
1																	
2																	
3																	
4																	
5																	
6																	
7																	
8																	
9	7000	128600	6083900	1087900	4996000	6083900	5460400	464400	(623500)	232200	(311750)	1484200	940250	1484200	940250	1.73	
10	7000	128600	6083900	1067700	5016200	6083900	5460400	444200	(623500)	222100	(311750)	1474100	940250	2958300	1880500	1.66	
11	5000	91700	4921100	947100	3974000	4921100	3930300	(43700)	(990800)	(21850)	(495400)	1230150	756600	4188450	2637100		
12	5000	91700	4921100	927000	3994100	4921100	3930300	(63800)	(990800)	(31900)	(495400)	1220100	756600	5408550	3393700		
13	5000	91700	4921100	906800	4014300	4921100	3930300	(84000)	(990800)	(42000)	(495400)	1210000	756600	6618550	4150300		
14	5000	91700	4921100	886600	4034500	4921100	3930300	(104200)	(990800)	(52100)	(495400)	1199900	756600	7818450	4906900		
15	5000	91700	4921100	866400	4054700	4921100	3930300	(124400)	(990800)	(62200)	(495400)	1189800	756600	9008250	5663500		
16	3500	64200	4018100	762900	3255200	4018100	2774100	(481100)	(1244000)	(240550)	(622000)	1011450	630000	10019700	6293500		
17	3500	64200	4018100	742800	3275300	4018100	2774100	(501200)	(1244000)	(250600)	(622000)	1001400	630000	11021100	6923500		
18	3500	64200	4018100	722600	3295500	4018100	2774100	(521400)	(1244000)	(260700)	(622000)	991300	630000	12012400	7553500		
19	3500	64200	2766100	702400	2063700	2766100	2774100	710400	8000	355200	4000	355200	4000	12367600	7557500	2.65	0.03
20	3500	64200	2766100	682200	2083900	2766100	2774100	690200	8000	345100	4000	345100	4000	12712700	7561500	2.58	0.03
21	1500	27600	1490600	553000	937600	1490600	1209400	271800	(281200)	135900	(140600)	135900	(140600)	12848600	7420900	1.01	
22	1500	27600	1490600	532800	957800	1490600	1209400	251600	(281200)	125800	(140600)	125800	(140600)	12974400	7280300	0.94	
23	1500	27600	1490600	512600	978000	1490600	1209400	231400	(281200)	115700	(140600)	115700	(140600)	13090100	7139700	0.86	
24	1500	27600	1490600	492400	998200	1490600	1209400	211200	(281200)	105600	(140600)	105600	(140600)	13195700	6999100	0.79	
25	1500	27600	1490600	472300	1018300	1490600	1209400	191100	(281200)	95550	(140600)	95550	(140600)	13291250	6858500	0.71	
26	1500	27600	1490600	452100	1038500	1490600	1209400	170900	(281200)	85450	(140600)	85450	(140600)	13376700	6717900	0.64	
27	1500	27600	1490600	431900	1058700	1490600	1209400	150700	(281200)	75350	(140600)	75350	(140600)	13452050	6577300	0.56	
28	1500	27600	1490600	411700	1078900	1490600	1209400	130500	(281200)	65250	(140600)	65250	(140600)	13517300	6436700	0.49	
29	1500	27600	1490600	391600	1099000	1490600	1209400	110400	(281200)	55200	(140600)	55200	(140600)	13572500	6296100	0.41	
30	1500	27600	1490600	371400	1119200	1490600	1209400	90200	(281200)	45100	(140600)	45100	(140600)	13617600	6155500	0.34	
31	1500	27600	1490600	351200	1139400	1490600	1209400	70000	(281200)	35000	(140600)	35000	(140600)	13652600	6014900	0.26	
32	1500	27600	1490600	331000	1159600	1490600	1209400	49800	(281200)	24900	(140600)	24900	(140600)	13677500	5874300	0.19	
33	1500	27600	1490600	310900	1179700	1490600	1209400	29700	(281200)	14850	(140600)	14850	(140600)	13692350	5733700	0.11	
34	1500	27600	1490600	290700	1199900	1490600	1209400	9500	(281200)	4750	(140600)	4750	(140600)	13697100	5593100	0.04	
35	1500	27600	1490600	270500	1220100	1490600	1209400	(10700)	(281200)	(5350)	(140600)	(5350)	(140600)	13691750	5452500		
TOTAL	79000	1450700	76718800	16478500	60240300	76718800	62583800	2343500	(14135000)	1171750	(7067500)	13691750	5452500		AVG=	0.32	

Table B-107

PROCESS A, NONREGULATED FERTILIZER CO. ECONOMICS, 500 MW., NEW UNIT, 2.0% S IN COAL, 28-14-0 FERTILIZER PRODUCTION

FIXED INVESTMENT = $ 16695000
TOTAL INITIAL INVESTMENT = $ 17865800
OVERALL INTEREST RATE OF RETURN WITH PAYMENT = 9.3%
OVERALL INTEREST RATE OF RETURN WITHOUT PAYMENT = NEG

YEARS REQUIRED FOR PAYOUT WITH PAYMENT: 7.4
NO PAYOUT WITHOUT PAYMENT

YEARS AFTER POWER UNIT START	ANNUAL OPERA-TION KW-HR/KW	TONS/YEAR FERTILIZER	TOTAL FERTILIZER MFG. COST, $/YEAR	ALTERNATIVE WET-LIMESTONE PROCESS COST AS PAYMENT TO FERTILIZER COMPANY FOR AIR POLLU-TION CONTROL, $/YEAR	NET FERTILIZER MFG COST, $/YEAR		NET FERTILIZER SALES REVENUE, $/YEAR	GROSS INCOME, $/YEAR		NET INCOME AFTER TAXES, $/YEAR		CASH FLOW, $/YEAR		CUMULATIVE CASH FLOW, $		ANNUAL RETURN ON INITIAL INVESTMENT, %	
					WITH PAYMENT	WITHOUT PAYMENT		WITH PAYMENT	WITHOUT PAYMENT	WITH PAYMENT	WITHOUT PAYMENT	WITH PAYMENT	WITHOUT PAYMENT	WITH PAYMENT	WITHOUT PAYMENT	WITH PAYMENT	WITHOUT PAYMENT
1	7000	173600	7832300	1800000	6032300	7832300	7301600	1269300	(530700)	634650	(265350)	2304150	1404150	2304150	1404150	3.55	
2	7000	173600	7832300	1772800	6059500	7832300	7301600	1242100	(530700)	621050	(265350)	2290550	1404150	4594700	2808300	3.48	
3	7000	173600	7832300	1749100	6083200	7832300	7301600	1218400	(530700)	609200	(265350)	2278700	1404150	6873400	4212450	3.41	
4	7000	173600	7832300	1718800	6113500	7832300	7301600	1188100	(530700)	594050	(265350)	2263550	1404150	9136950	5616600	3.33	
5	7000	173600	7832300	1690600	6141700	7832300	7301600	1159900	(530700)	579950	(265350)	2249450	1404150	11386400	7020750	3.25	
6	7000	173600	7832300	1663400	6168900	7832300	7301600	1132700	(530700)	566350	(265350)	2235850	1404150	13622250	8424900	3.17	
7	7000	173600	7832300	1635900	6196400	7832300	7301600	1105200	(530700)	552600	(265350)	2222100	1404150	15844350	9829050	3.09	
8	7000	173600	7832300	1608700	6223600	7832300	7301600	1078000	(530700)	539000	(265350)	2208500	1404150	18052850	11233200	3.02	
9	7000	173600	7832300	1581200	6251100	7832300	7301600	1050500	(530700)	525250	(265350)	2194750	1404150	20247600	12637350	2.94	
10	7000	173600	7832300	1553800	6278500	7832300	7301600	1023100	(530700)	511550	(265350)	2181050	1404150	22428650	14041500	2.86	
11	5000	123900	4676400	1379800	3296600	4676400	5268200	1971600	591800	985800	295900	985800	295900	23414450	14337400	5.52	1.66
12	5000	123900	4676400	1352300	3324100	4676400	5268200	1944100	591800	972050	295900	972050	295900	24386500	14633300	5.44	1.66
13	5000	123900	4676400	1325100	3351300	4676400	5268200	1916900	591800	958450	295900	958450	295900	25344950	14929200	5.36	1.66
14	5000	123900	4676400	1297900	3378500	4676400	5268200	1889700	591800	944850	295900	944850	295900	26289800	15225100	5.29	1.66
15	5000	123900	4676400	1270400	3406000	4676400	5268200	1862200	591800	931100	295900	931100	295900	27220900	15521000	5.21	1.66
16	3500	86700	3523400	1114100	2409300	3523400	3721200	1311900	197800	655950	98900	655950	98900	27876850	15619900	3.67	0.55
17	3500	86700	3523400	1086700	2436700	3523400	3721200	1284500	197800	642250	98900	642250	98900	28519100	15718800	3.59	0.55
18	3500	86700	3523400	1059200	2464200	3523400	3721200	1257000	197800	628500	98900	628500	98900	29147600	15817700	3.52	0.55
19	3500	86700	3523400	1032000	2491400	3523400	3721200	1229800	197800	614900	98900	614900	98900	29762500	15916600	3.44	0.55
20	3500	86700	3523400	1004500	2518900	3523400	3721200	1202300	197800	601150	98900	601150	98900	30363650	16015500	3.36	0.55
21	1500	37200	1898900	827100	1071800	1898900	1623000	551200	(275900)	275600	(137950)	275600	(137950)	30639250	15877550	1.54	
22	1500	37200	1898900	799800	1099100	1898900	1623000	523900	(275900)	261950	(137950)	261950	(137950)	30901200	15739600	1.47	
23	1500	37200	1898900	772400	1126500	1898900	1623000	496500	(275900)	248250	(137950)	248250	(137950)	31149450	15601650	1.39	
24	1500	37200	1898900	745100	1153800	1898900	1623000	469200	(275900)	234600	(137950)	234600	(137950)	31384050	15463700	1.31	
25	1500	37200	1898900	717700	1181200	1898900	1623000	441800	(275900)	220900	(137950)	220900	(137950)	31604950	15325750	1.24	
26	1500	37200	1898900	690400	1208500	1898900	1623000	414500	(275900)	207250	(137950)	207250	(137950)	31812200	15187800	1.16	
27	1500	37200	1898900	663000	1235900	1898900	1623000	387100	(275900)	193550	(137950)	193550	(137950)	32005750	15049850	1.08	
28	1500	37200	1898900	635500	1263400	1898900	1623000	359600	(275900)	179800	(137950)	179800	(137950)	32185550	14911900	1.01	
29	1500	37200	1898900	608300	1290600	1898900	1623000	332400	(275900)	166200	(137950)	166200	(137950)	32351750	14773950	0.93	
30	1500	37200	1898900	580800	1318100	1898900	1623000	304900	(275900)	152450	(137950)	152450	(137950)	32504200	14636000	0.85	
31	1500	37200	1898900	553600	1345300	1898900	1623000	277700	(275900)	138850	(137950)	138850	(137950)	32643050	14498050	0.78	
32	1500	37200	1898900	526100	1372800	1898900	1623000	250200	(275900)	125100	(137950)	125100	(137950)	32768150	14360100	0.70	
33	1500	37200	1898900	498900	1400000	1898900	1623000	223000	(275900)	111500	(137950)	111500	(137950)	32879650	14222150	0.62	
34	1500	37200	1898900	471400	1427500	1898900	1623000	195500	(275900)	97750	(137950)	97750	(137950)	32977400	14084200	0.55	
35	1500	37200	1898900	444200	1454700	1898900	1623000	168300	(275900)	84150	(137950)	84150	(137950)	33061550	13946250	0.47	
TOTAL	135000	3347000	147805500	38230600	109574900	147805500	142308000	32733100	(549750)	16366550	(274875)	33061550	13946250		AVG=	2.62	

Table B-108

PROCESS A, NONREGULATED FERTILIZER CO. ECONOMICS, 500 MW., NEW UNIT, 3.5% S IN COAL, 28-14-0 FERTILIZER PRODUCTION

FIXED INVESTMENT = $ 21470000
TOTAL INITIAL INVESTMENT = $ 23360500
OVERALL INTEREST RATE OF RETURN WITH PAYMENT = 13.0%
OVERALL INTEREST RATE OF RETURN WITHOUT PAYMENT = 5.7%

YEARS REQUIRED FOR PAYOUT WITH PAYMENT: 6.1
YEARS REQUIRED FOR PAYOUT WITHOUT PAYMENT: 8.7

YEARS AFTER POWER UNIT START	ANNUAL OPERATION KW-HR/KW	TONS/YEAR FERTILIZER	TOTAL FERTILIZER MFG. COST, $/YEAR	ALTERNATIVE WET-LIMESTONE PROCESS COST AS PAYMENT TO FERTILIZER COMPANY FOR AIR POLLUTION CONTROL, $/YEAR	NET FERTILIZER MFG COST, $/YEAR		NET FERTILIZER SALES REVENUE, $/YEAR	GROSS INCOME, $/YEAR		NET INCOME AFTER TAXES, $/YEAR		CASH FLOW, $/YEAR		CUMULATIVE CASH FLOW, $		ANNUAL RETURN ON INITIAL INVESTMENT, %	
					WITH PAYMENT	WITHOUT PAYMENT		WITH PAYMENT	WITHOUT PAYMENT	WITH PAYMENT	WITHOUT PAYMENT	WITH PAYMENT	WITHOUT PAYMENT	WITH PAYMENT	WITHOUT PAYMENT	WITH PAYMENT	WITHOUT PAYMENT
1	7000	303800	11858100	2150200	9707900	11858100	12492000	2784100	633900	1392050	316950	3539050	2463950	3539050	2463950	5.96	1.36
2	7000	303800	11858100	2119600	9738500	11858100	12492000	2753500	633900	1376750	316950	3523750	2463950	7062800	4927900	5.89	1.36
3	7000	303800	11858100	2089200	9768900	11858100	12492000	2723100	633900	1361550	316950	3508550	2463950	10571350	7391850	5.83	1.36
4	7000	303800	11858100	2058700	9799400	11858100	12492000	2692600	633900	1346300	316950	3493300	2463950	14064650	9855800	5.76	1.36
5	7000	303800	11858100	2028100	9830000	11858100	12492000	2662000	633900	1331000	316950	3478000	2463950	17542650	12319750	5.70	1.36
6	7000	303800	11858100	1997500	9860600	11858100	12492000	2631400	633900	1315700	316950	3462700	2463950	21005350	14783700	5.63	1.36
7	7000	303800	11858100	1967100	9891000	11858100	12492000	2601000	633900	1300500	316950	3447500	2463950	24452850	17247650	5.57	1.36
8	7000	303800	11858100	1936600	9921500	11858100	12492000	2570500	633900	1285250	316950	3432250	2463950	27885100	19711600	5.50	1.36
9	7000	303800	11858100	1906000	9952100	11858100	12492000	2539900	633900	1269950	316950	3416950	2463950	31302050	22175550	5.44	1.36
10	7000	303800	11858100	1875600	9982500	11858100	12492000	2509500	633900	1254750	316950	3401750	2463950	34703800	24639500	5.37	1.36
11	5000	217000	7296300	1640100	5656200	7296300	9052000	3395800	1755700	1697900	877850	1697900	877850	36401700	25517350	7.27	3.76
12	5000	217000	7296300	1610000	5686300	7296300	9052000	3365700	1755700	1682850	877850	1682850	877850	38084550	26395200	7.20	3.76
13	5000	217000	7296300	1579400	5716900	7296300	9052000	3335100	1755700	1667550	877850	1667550	877850	39752100	27273050	7.14	3.76
14	5000	217000	7296300	1549000	5747300	7296300	9052000	3304700	1755700	1652350	877850	1652350	877850	41404450	28150900	7.07	3.76
15	5000	217000	7296300	1518400	5777900	7296300	9052000	3274100	1755700	1637050	877850	1637050	877850	43041500	29028750	7.01	3.76
16	3500	151900	5434500	1311600	4122900	5434500	6415000	2292100	980500	1146050	490250	1146050	490250	44187550	29519000	4.91	2.10
17	3500	151900	5434500	1281200	4153300	5434500	6415000	2261700	980500	1130850	490250	1130850	490250	45318400	30009250	4.84	2.10
18	3500	151900	5434500	1250600	4183900	5434500	6415000	2231100	980500	1115550	490250	1115550	490250	46433950	30499500	4.78	2.10
19	3500	151900	5434500	1220100	4214400	5434500	6415000	2200600	980500	1100300	490250	1100300	490250	47534250	30989750	4.71	2.10
20	3500	151900	5434500	1189700	4244800	5434500	6415000	2170200	980500	1085100	490250	1085100	490250	48619350	31480000	4.65	2.10
21	1500	65300	2851500	952200	1899300	2851500	2820000	920700	(31500)	460350	(15750)	460350	(15750)	49079700	31464250	1.97	
22	1500	65300	2851500	921600	1929900	2851500	2820000	890100	(31500)	445050	(15750)	445050	(15750)	49524750	31448500	1.91	
23	1500	65300	2851500	891100	1960400	2851500	2820000	859600	(31500)	429800	(15750)	429800	(15750)	49954550	31432750	1.84	
24	1500	65300	2851500	860700	1990800	2851500	2820000	829200	(31500)	414600	(15750)	414600	(15750)	50369150	31417000	1.77	
25	1500	65300	2851500	830100	2021400	2851500	2820000	798600	(31500)	399300	(15750)	399300	(15750)	50768650	31401250	1.71	
26	1500	65300	2851500	799500	2052000	2851500	2820000	768000	(31500)	384000	(15750)	384000	(15750)	51152450	31385500	1.64	
27	1500	65300	2851500	769200	2082300	2851500	2820000	737700	(31500)	368850	(15750)	368850	(15750)	51521300	31369750	1.58	
28	1500	65300	2851500	738600	2113100	2851500	2820000	706900	(31500)	353450	(15750)	353450	(15750)	51874750	31354000	1.51	
29	1500	65300	2851500	708100	2143400	2851500	2820000	676600	(31500)	338300	(15750)	338300	(15750)	52213050	31338250	1.45	
30	1500	65300	2851500	677400	2174100	2851500	2820000	645900	(31500)	322950	(15750)	322950	(15750)	52536000	31322500	1.38	
31	1500	65300	2851500	647100	2204400	2851500	2820000	615600	(31500)	307800	(15750)	307800	(15750)	52843800	31306750	1.32	
32	1500	65300	2851500	616500	2235000	2851500	2820000	585000	(31500)	292500	(15750)	292500	(15750)	53136300	31291000	1.25	
33	1500	65300	2851500	585900	2265600	2851500	2820000	554400	(31500)	277200	(15750)	277200	(15750)	53413500	31275250	1.19	
34	1500	65300	2851500	555600	2295900	2851500	2820000	524100	(31500)	262050	(15750)	262050	(15750)	53675550	31259500	1.12	
35	1500	65300	2851500	525000	2326500	2851500	2820000	493500	(31500)	246750	(15750)	246750	(15750)	53922300	31243750	1.06	
TOTAL	135000	5862000	225007500	65357100	179650400	225007500	244555000	64904600	19547500	32452300	9773750	53922300	31243750		AVG=	3.97	1.20

Table B-109

PROCESS A, NONREGULATED FERTILIZER CO. ECONOMICS, 500 MW., EXISTING UNIT, 3.5% S IN COAL, 28-14-0 FERTILIZER PRODUCTION

FIXED INVESTMENT = $ 22320000
TOTAL INITIAL INVESTMENT = $ 24257700
OVERALL INTEREST RATE OF RETURN WITH PAYMENT = 11.0%
OVERALL INTEREST RATE OF RETURN WITHOUT PAYMENT = 1.4%

YEARS REQUIRED FOR PAYOUT WITH PAYMENT: 6.4
YEARS REQUIRED FOR PAYOUT WITHOUT PAYMENT: 9.8

YEARS AFTER POWER UNIT START	ANNUAL OPERA- TION KW-HR/ KW	TONS/YEAR FERTILIZER	TOTAL FERTILIZER MFG. COST, $/YEAR	ALTERNATIVE WET-LIMESTONE PROCESS COST AS PAYMENT TO FERTILIZER COMPANY FOR AIR POLLU- TION CONTROL, $/YEAR	NET FERTILIZER MFG COST, $/YEAR		NET FERTILIZER SALES REVENUE, $/YEAR	GROSS INCOME, $/YEAR		NET INCOME AFTER TAXES, $/YEAR		CASH FLOW, $/YEAR		CUMULATIVE CASH FLOW, $		ANNUAL RETURN ON INITIAL INVESTMENT, %	
					WITH PAYMENT	WITHOUT PAYMENT		WITH PAYMENT	WITHOUT PAYMENT	WITH PAYMENT	WITHOUT PAYMENT	WITH PAYMENT	WITHOUT PAYMENT	WITH PAYMENT	WITHOUT PAYMENT	WITH PAYMENT	WITHOUT PAYMENT
1																	
2																	
3																	
4	7000	310800	12410000	2261500	10148500	12410000	12764600	2616100	354600	1308050	177300	3540050	2409300	3540050	2409300	5.39	0.73
5	7000	310800	12410000	2226100	10183900	12410000	12764600	2580700	354600	1290350	177300	3522350	2409300	7062400	4818600	5.32	0.73
6	7000	310800	12410000	2191000	10219000	12410000	12764600	2545600	354600	1272800	177300	3504800	2409300	10567200	7227900	5.25	0.73
7	7000	310800	12410000	2155600	10254400	12410000	12764600	2510200	354600	1255100	177300	3487100	2409300	14054300	9637200	5.17	0.73
8	7000	310800	12410000	2120500	10289500	12410000	12764600	2475100	354600	1237550	177300	3469550	2409300	17523850	12046500	5.10	0.73
9	7000	310800	12410000	2085100	10324900	12410000	12764600	2439700	354600	1219850	177300	3451850	2409300	20975700	14455800	5.03	0.73
10	7000	310800	12410000	2050000	10360000	12410000	12764600	2404600	354600	1202300	177300	3434300	2409300	24410000	16865100	4.96	0.73
11	5000	222000	9877100	1804000	8073100	9877100	9253000	1179900	(624100)	589950	(312050)	2821950	1919950	27231950	18785050	2.43	
12	5000	222000	9877100	1768900	8108200	9877100	9253000	1144800	(624100)	572400	(312050)	2804400	1919950	30036350	20705000	2.36	
13	5000	222000	9877100	1733500	8143600	9877100	9253000	1109400	(624100)	554700	(312050)	2786700	1919950	32823050	22624950	2.29	
14	5000	222000	7645100	1698300	5946800	7645100	9253000	3306200	1607900	1653100	803950	1653100	803950	34476150	23428900	6.81	3.31
15	5000	222000	7645100	1663000	5982100	7645100	9253000	3270900	1607900	1635450	803950	1635450	803950	36111600	24232850	6.74	3.31
16	3500	155400	5692000	1447600	4244400	5692000	6561000	2316600	869000	1158300	434500	1158300	434500	37269900	24667350	4.77	1.79
17	3500	155400	5692000	1412300	4279700	5692000	6561000	2281300	869000	1140650	434500	1140650	434500	38410550	25101850	4.70	1.79
18	3500	155400	5692000	1377100	4314900	5692000	6561000	2246100	869000	1123050	434500	1123050	434500	39533600	25536350	4.63	1.79
19	3500	155400	5692000	1341800	4350200	5692000	6561000	2210800	869000	1105400	434500	1105400	434500	40639000	25970850	4.56	1.79
20	3500	155400	5692000	1306600	4385400	5692000	6561000	2175600	869000	1087800	434500	1087800	434500	41726800	26405350	4.49	1.79
21	1500	66800	3243100	1061200	2181900	3243100	2883800	701900	(359300)	350950	(179650)	350950	(179650)	42077750	26225700	1.45	
22	1500	66800	3243100	1025900	2217200	3243100	2883800	666600	(359300)	333300	(179650)	333300	(179650)	42411050	26046050	1.37	
23	1500	66800	3243100	990700	2252400	3243100	2883800	631400	(359300)	315700	(179650)	315700	(179650)	42726750	25866400	1.30	
24	1500	66800	3243100	955400	2287700	3243100	2883800	596100	(359300)	298050	(179650)	298050	(179650)	43024800	25686750	1.23	
25	1500	66800	3243100	920200	2322900	3243100	2883800	560900	(359300)	280450	(179650)	280450	(179650)	43305250	25507100	1.16	
26	1500	66800	3243100	884900	2358200	3243100	2883800	525600	(359300)	262800	(179650)	262800	(179650)	43568050	25327450	1.08	
27	1500	66800	3243100	849700	2393400	3243100	2883800	490400	(359300)	245200	(179650)	245200	(179650)	43813250	25147800	1.01	
28	1500	66800	3243100	814300	2428800	3243100	2883800	455000	(359300)	227500	(179650)	227500	(179650)	44040750	24968150	0.94	
29	1500	66800	3243100	779200	2463900	3243100	2883800	419900	(359300)	209950	(179650)	209950	(179650)	44250700	24788500	0.87	
30	1500	66800	3243100	743800	2499300	3243100	2883800	384500	(359300)	192250	(179650)	192250	(179650)	44442950	24608850	0.79	
31	1500	66800	3243100	708700	2534400	3243100	2883800	349400	(359300)	174700	(179650)	174700	(179650)	44617650	24429200	0.72	
32	1500	66800	3243100	673300	2569800	3243100	2883800	314000	(359300)	157000	(179650)	157000	(179650)	44774650	24249550	0.65	
33	1500	66800	3243100	638200	2604900	3243100	2883800	278900	(359300)	139450	(179650)	139450	(179650)	44914100	24069900	0.57	
34	1500	66800	3243100	602800	2640300	3243100	2883800	243500	(359300)	121750	(179650)	121750	(179650)	45035850	23890250	0.50	
35	1500	66800	3243100	567700	2675400	3243100	2883800	208400	(359300)	104200	(179650)	104200	(179650)	45140050	23710600	0.43	
TOTAL	114000	5064600	208898000	42858900	166039100	208898000	211679200	45640100	2781200	22820050	1390600	45140050	23710600		AVG=	2.94	0.19

Table B-110

PROCESS A, NONREGULATED FERTILIZER CO. ECONOMICS, 500 MW., NEW UNIT, 5.0% S IN COAL, 28-14-0 FERTILIZER PRODUCTION

FIXED INVESTMENT = $ 26130000
TOTAL INITIAL INVESTMENT = $ 28523100
OVERALL INTEREST RATE OF RETURN WITH PAYMENT = 17.4%
OVERALL INTEREST RATE OF RETURN WITHOUT PAYMENT = 11.4%

YEARS REQUIRED FOR PAYOUT WITH PAYMENT: 5.0
YEARS REQUIRED FOR PAYOUT WITHOUT PAYMENT: 6.6

YEARS AFTER POWER UNIT START	ANNUAL OPERATION KW-HR/KW	TONS/YEAR FERTILIZER	TOTAL FERTILIZER MFG. COST, $/YEAR	ALTERNATIVE WET-LIMESTONE PROCESS COST AS PAYMENT TO FERTILIZER COMPANY FOR AIR POLLUTION CONTROL, $/YEAR	NET FERTILIZER MFG COST, $/YEAR WITH PAYMENT	NET FERTILIZER MFG COST, $/YEAR WITHOUT PAYMENT	NET FERTILIZER SALES REVENUE, $/YEAR	GROSS INCOME, $/YEAR WITH PAYMENT	GROSS INCOME, $/YEAR WITHOUT PAYMENT	NET INCOME AFTER TAXES, $/YEAR WITH PAYMENT	NET INCOME AFTER TAXES, $/YEAR WITHOUT PAYMENT	CASH FLOW, $/YEAR WITH PAYMENT	CASH FLOW, $/YEAR WITHOUT PAYMENT	CUMULATIVE CASH FLOW, $ WITH PAYMENT	CUMULATIVE CASH FLOW, $ WITHOUT PAYMENT	ANNUAL RETURN ON INITIAL INVESTMENT, % WITH PAYMENT	ANNUAL RETURN ON INITIAL INVESTMENT, % WITHOUT PAYMENT
1	7000	434000	14818300	2506500	12311800	14818300	17516200	5204400	2697900	2602200	1348950	5215200	3961950	5215200	3961950	9.12	4.73
2	7000	434000	14818300	2473000	12345300	14818300	17516200	5170900	2697900	2585450	134895C	5198450	3961950	10413650	7923900	9.06	4.73
3	7000	434000	14818300	2439300	12379000	14818300	17516200	5137200	2697900	2568600	1348950	5181600	3961950	15595250	11885850	9.01	4.73
4	7000	434000	14818300	2405800	12412500	14818300	17516200	5103700	2697900	2551850	1348950	5164850	3961950	20760100	15847800	8.95	4.73
5	7000	434000	14818300	2372100	12446200	14818300	17516200	5070000	2697900	2535000	1348950	5148000	3961950	25908100	19809750	8.89	4.73
6	7000	434000	14818300	2338600	12479700	14818300	17516200	5036500	2697900	2518250	1348950	5131250	3961950	31039350	23771700	8.83	4.73
7	7000	434000	14818300	2304900	12513400	14818300	17516200	5002800	2697900	2501400	1348950	5114400	3961950	36153750	27733650	8.77	4.73
8	7000	434000	14818300	2271500	12546800	14818300	17516200	4969400	2697900	2484700	1348950	5097700	3961950	41251450	31695600	8.71	4.73
9	7000	434000	14818300	2238000	12580300	14818300	17516200	4935900	2697900	2467950	1348950	5080950	3961950	46332400	35657550	8.65	4.73
10	7000	434000	14818300	2204300	12614000	14818300	17516200	4902200	2697900	2451100	1348950	5064100	3961950	51396500	39619500	8.59	4.73
11	5000	309800	9148200	1903900	7244300	9148200	12726600	5482300	3578400	2741150	1789200	2741150	1789200	54137650	41408700	9.61	6.27
12	5000	309800	9148200	1870200	7278000	9148200	12726600	5448600	3578400	2724300	1789200	2724300	1789200	56861950	43197900	9.55	6.27
13	5000	309800	9148200	1836700	7311500	9148200	12726600	5415100	3578400	2707550	1789200	2707550	1789200	59569500	44987100	9.49	6.27
14	5000	309800	9148200	1803000	7345200	9148200	12726600	5381400	3578400	2690700	1789200	2690700	1789200	62260200	46776300	9.43	6.27
15	5000	309800	9148200	1769500	7378700	9148200	12726600	5347900	3578400	2673950	1789200	2673950	1789200	64934150	48565500	9.37	6.27
16	3500	217000	6794900	1512100	5282800	6794900	9051000	3768200	2256100	1884100	1128050	1884100	1128050	66818250	49693550	6.61	3.95
17	3500	217000	6794900	1478400	5316500	6794900	9051000	3734500	2256100	1867250	1128050	1867250	1128050	68685500	50821600	6.55	3.95
18	3500	217000	6794900	1444900	5350000	6794900	9051000	3701000	2256100	1850500	1128050	1850500	1128050	70536000	51949650	6.49	3.95
19	3500	217000	6794900	1411300	5383600	6794900	9051000	3667400	2256100	1833700	1128050	1833700	1128050	72369700	53077700	6.43	3.95
20	3500	217000	6794900	1377800	5417100	6794900	9051000	3633900	2256100	1816950	1128050	1816950	1128050	74186650	54205750	6.37	3.95
21	1500	92800	3522800	1078200	2444600	3522800	3977400	1532800	454600	766400	227300	766400	227300	74953050	54433050	2.69	0.80
22	1500	92800	3522800	1044700	2478100	3522800	3977400	1499300	454600	749650	227300	749650	227300	75702700	54660350	2.63	0.80
23	1500	92800	3522800	1011900	2510900	3522800	3977400	1466500	454600	733250	227300	733250	227300	76435950	54887650	2.57	0.80
24	1500	92800	3522800	977500	2545300	3522800	3977400	1432100	454600	716050	227300	716050	227300	77152000	55114950	2.51	0.80
25	1500	92800	3522800	944000	2578800	3522800	3977400	1398600	454600	699300	227300	699300	227300	77851300	55342250	2.45	0.80
26	1500	92800	3522800	910300	2612500	3522800	3977400	1364900	454600	682450	227300	682450	227300	78533750	55569550	2.39	0.80
27	1500	92800	3522800	876800	2646000	3522800	3977400	1331400	454600	665700	227300	665700	227300	79199450	55796850	2.33	0.80
28	1500	92800	3522800	843100	2679700	3522800	3977400	1297700	454600	648850	227300	648850	227300	79848300	56024150	2.27	0.80
29	1500	92800	3522800	809600	2713200	3522800	3977400	1264200	454600	632100	227300	632100	227300	80480400	56251450	2.22	0.80
30	1500	92800	3522800	776200	2746600	3522800	3977400	1230800	454600	615400	227300	615400	227300	81095400	56479750	2.16	0.80
31	1500	92800	3522800	742500	2780300	3522800	3977400	1197100	454600	598550	227300	598550	227300	81694350	56706050	2.10	0.80
32	1500	92800	3522800	708800	2814000	3522800	3977400	1163400	454600	581700	227300	581700	227300	82276050	56933350	2.04	0.80
33	1500	92800	3522800	675300	2847500	3522800	3977400	1129900	454600	564950	227300	564950	227300	82841000	57160650	1.98	0.80
34	1500	92800	3522800	641800	2881000	3522800	3977400	1096400	454600	548200	227300	548200	227300	83389200	57387950	1.92	0.80
35	1500	92800	3522800	608100	2914700	3522800	3977400	1062700	454600	531350	227300	531350	227300	83920550	57615250	1.86	0.80
TOTAL	135000	8366000	280740500	52610600	228129900	280740500	343711000	115581100	62970500	57790550	31485250	83920550	57615250		AVG=	5.79	3.15

Table B-111

PROCESS B, NONREGULATED FERTILIZER CO. ECONOMICS, 1000 MW., NEW UNIT, 3.5% S IN COAL, 28-14-0 FERTILIZER PRODUCTION

FIXED INVESTMENT = $ 34500000
TOTAL INITIAL INVESTMENT = $ 37744200
OVERALL INTEREST RATE OF RETURN WITH PAYMENT = 17.9%
OVERALL INTEREST RATE OF RETURN WITHOUT PAYMENT = 12.0%

YEARS REQUIRED FOR PAYOUT WITH PAYMENT: 4.9
YEARS REQUIRED FOR PAYOUT WITHOUT PAYMENT: 6.4

YEARS AFTER POWER UNIT START	ANNUAL OPERATION KW-HR/KW	TONS/YEAR FERTILIZER	TOTAL FERTILIZER MFG. COST, $/YEAR	ALTERNATIVE WET-LIMESTONE PROCESS COST AS PAYMENT TO FERTILIZER COMPANY FOR AIR POLLUTION CONTROL, $/YEAR	NET FERTILIZER MFG COST, $/YEAR		NET FERTILIZER SALES REVENUE, $/YEAR	GROSS INCOME, $/YEAR		NET INCOME AFTER TAXES, $/YEAR		CASH FLOW, $/YEAR		CUMULATIVE CASH FLOW, $		ANNUAL RETURN ON INITIAL INVESTMENT, %	
					WITH PAYMENT	WITHOUT PAYMENT		WITH PAYMENT	WITHOUT PAYMENT	WITH PAYMENT	WITHOUT PAYMENT	WITH PAYMENT	WITHOUT PAYMENT	WITH PAYMENT	WITHOUT PAYMENT	WITH PAYMENT	WITHOUT PAYMENT
1	7000	587500	19450800	3362400	16088400	19450800	23270900	7182500	3820100	3591250	1910050	7041250	5360050	7041250	5360050	9.51	5.06
2	7000	587500	19450800	3317000	16133800	19450800	23270900	7137100	3820100	3568550	1910050	7018550	5360050	14059800	10720100	9.45	5.06
3	7000	587500	19450800	3271900	16178900	19450800	23270900	7092000	3820100	3546000	1910050	6996000	5360050	21055800	16080150	9.39	5.06
4	7000	587500	19450800	3226500	16224300	19450800	23270900	7046600	3820100	3523300	1910050	6973300	5360050	28029100	21440200	9.33	5.06
5	7000	587500	19450800	3181200	16269600	19450800	23270900	7001300	3820100	3500650	1910050	6950650	5360050	34979750	26800250	9.27	5.06
6	7000	587500	19450800	3135800	16315000	19450800	23270900	6955900	3820100	3477950	1910050	6927950	5360050	41907700	32160300	9.21	5.06
7	7000	587500	19450800	3090700	16360100	19450800	23270900	6910800	3820100	3455400	1910050	6905400	5360050	48813100	37520350	9.15	5.06
8	7000	587500	19450800	3045400	16405400	19450800	23270900	6865500	3820100	3432750	1910050	6882750	5360050	55695850	42880400	9.09	5.06
9	7000	587500	19450800	3000000	16450800	19450800	23270900	6820100	3820100	3410050	1910050	6860050	5360050	62555900	48240450	9.03	5.06
10	7000	587500	19450800	2954900	16495900	19450800	23270900	6775000	3820100	3387500	1910050	6837500	5360050	69393400	53600500	8.97	5.06
11	5000	419700	11984900	2565100	9419800	11984900	16972700	7552900	4987800	3776450	2493900	3776450	2493900	73169850	56094400	10.01	6.61
12	5000	419700	11984900	2519800	9465100	11984900	16972700	7507600	4987800	3753800	2493900	3753800	2493900	76923650	58588300	9.95	6.61
13	5000	419700	11984900	2474500	9510400	11984900	16972700	7462300	4987800	3731150	2493900	3731150	2493900	80654800	61082200	9.89	6.61
14	5000	419700	11984900	2429300	9555600	11984900	16972700	7417100	4987800	3708550	2493900	3708550	2493900	84363350	63576100	9.83	6.61
15	5000	419700	11984900	2384000	9600900	11984900	16972700	7371800	4987800	3685900	2493900	3685900	2493900	88049250	66070000	9.77	6.61
16	3500	293800	8894900	2053500	6841400	8894900	12098700	5257300	3203800	2628650	1601900	2628650	1601900	90677900	67671900	6.96	4.24
17	3500	293800	8894900	2008400	6886500	8894900	12098700	5212200	3203800	2606100	1601900	2606100	1601900	93284000	69273800	6.90	4.24
18	3500	293800	8894900	1963100	6931800	8894900	12098700	5166900	3203800	2583450	1601900	2583450	1601900	95867450	70875700	6.84	4.24
19	3500	293800	8894900	1917700	6977200	8894900	12098700	5121500	3203800	2560750	1601900	2560750	1601900	98428200	72477600	6.78	4.24
20	3500	293800	8894900	1872400	7022500	8894900	12098700	5076200	3203800	2538100	1601900	2538100	1601900	100966300	74079500	6.72	4.24
21	1500	126300	4603600	1496500	3107100	4603600	5366500	2259400	762900	1129700	381450	1129700	381450	102096000	74460950	2.99	1.01
22	1500	126300	4603600	1451200	3152400	4603600	5366500	2214100	762900	1107050	381450	1107050	381450	103203050	74842400	2.93	1.01
23	1500	126300	4603600	1405800	3197800	4603600	5366500	2168700	762900	1084350	381450	1084350	381450	104287400	75223850	2.87	1.01
24	1500	126300	4603600	1360700	3242900	4603600	5366500	2123600	762900	1061800	381450	1061800	381450	105349200	75605300	2.81	1.01
25	1500	126300	4603600	1315400	3288200	4603600	5366500	2078300	762900	1039150	381450	1039150	381450	106388350	75986750	2.75	1.01
26	1500	126300	4603600	1270000	3333600	4603600	5366500	2032900	762900	1016450	381450	1016450	381450	107404800	76368200	2.69	1.01
27	1500	126300	4603600	1224700	3378900	4603600	5366500	1987600	762900	993800	381450	993800	381450	108398600	76749650	2.63	1.01
28	1500	126300	4603600	1179500	3424100	4603600	5366500	1942400	762900	971200	381450	971200	381450	109369800	77131100	2.57	1.01
29	1500	126300	4603600	1134200	3469400	4603600	5366500	1897100	762900	948550	381450	948550	381450	110318350	77512550	2.51	1.01
30	1500	126300	4603600	1088800	3514800	4603600	5366500	1851700	762900	925850	381450	925850	381450	111244200	77894000	2.45	1.01
31	1500	126300	4603600	1043700	3559900	4603600	5366500	1806600	762900	903300	381450	903300	381450	112147500	78275450	2.39	1.01
32	1500	126300	4603600	998400	3605200	4603600	5366500	1761300	762900	880650	381450	880650	381450	113028150	78656900	2.33	1.01
33	1500	126300	4603600	953000	3650600	4603600	5366500	1715900	762900	857950	381450	857950	381450	113886100	79038350	2.27	1.01
34	1500	126300	4603600	907700	3695900	4603600	5366500	1670600	762900	835300	381450	835300	381450	114721400	79419800	2.21	1.01
35	1500	126300	4603600	862500	3741100	4603600	5366500	1625400	762900	812700	381450	812700	381450	115534100	79801250	2.15	1.01
TOTAL	135000	11337000	367961000	71465700	296495300	367961000	458563500	162068200	90602500	81034100	45301250	115534100	79801250		AVG=	6.13	3.43

Table B-112

PROCESS A, NONREGULATED FERTILIZER CO. ECONOMICS, 1000 MW., EXISTING UNIT, 3.5% S IN COAL, 28-14-0 FERTILIZER PRODUCTION

FIXED INVESTMENT = $ 36550000
TOTAL INITIAL INVESTMENT = $ 39908800
OVERALL INTEREST RATE OF RETURN WITH PAYMENT = 15.6%
OVERALL INTEREST RATE OF RETURN WITHOUT PAYMENT = 9.1%

YEARS REQUIRED FOR PAYOUT WITH PAYMENT: 5.2
YEARS REQUIRED FOR PAYOUT WITHOUT PAYMENT: 6.9

YEARS AFTER POWER UNIT START	ANNUAL OPERATION KW-HR/KW	TONS/YEAR FERTILIZER	TOTAL FERTILIZER MFG. COST, $/YEAR	ALTERNATIVE WET-LIMESTONE PROCESS COST AS PAYMENT TO FERTILIZER COMPANY FOR AIR POLLUTION CONTROL, $/YEAR	NET FERTILIZER MFG COST, $/YEAR		NET FERTILIZER SALES REVENUE, $/YEAR	GROSS INCOME, $/YEAR		NET INCOME AFTER TAXES, $/YEAR		CASH FLOW, $/YEAR		CUMULATIVE CASH FLOW, $		ANNUAL RETURN ON INITIAL INVESTMENT, %	
					WITH PAYMENT	WITHOUT PAYMENT		WITH PAYMENT	WITHOUT PAYMENT	WITH PAYMENT	WITHOUT PAYMENT	WITH PAYMENT	WITHOUT PAYMENT	WITH PAYMENT	WITHOUT PAYMENT	WITH PAYMENT	WITHOUT PAYMENT
1																	
2																	
3																	
4	7000	607600	20792300	3587300	17205000	20792300	24018400	6813400	3226100	3406700	1613050	7061700	5268050	7061700	5268050	8.54	4.04
5	7000	607600	20792300	3533800	17258500	20792300	24018400	6759900	3226100	3379950	1613050	7034950	5268050	14096650	10536100	8.47	4.04
6	7000	607600	20792300	3480600	17311700	20792300	24018400	6706700	3226100	3353350	1613050	7008350	5268050	21105000	15804150	8.40	4.04
7	7000	607600	20792300	3427200	17365100	20792300	24018400	6653300	3226100	3326650	1613050	6981650	5268050	28086650	21072200	8.34	4.04
8	7000	607600	20792300	3373900	17418400	20792300	24018400	6600000	3226100	3300000	1613050	6955000	5268050	35041650	26340250	8.27	4.04
9	7000	607600	20792300	3319900	17472400	20792300	24018400	6546000	3226100	3273000	1613050	6928000	5268050	41969650	31608300	8.20	4.04
10	7000	607600	20792300	3267200	17525100	20792300	24018400	6493300	3226100	3246650	1613050	6901650	5268050	48871300	36876350	8.14	4.04
11	5000	433800	16433000	2857000	13576000	16433000	17508200	3932200	1075200	1966100	537600	5621100	4192600	54492400	41068950	4.93	1.35
12	5000	433800	16433000	2803800	13629200	16433000	17508200	3879000	1075200	1939500	537600	5594500	4192600	60086900	45261550	4.86	1.35
13	5000	433800	16433000	2750300	13682700	16433000	17508200	3825500	1075200	1912750	537600	5567750	4192600	65654650	49454150	4.79	1.35
14	5000	433800	12778000	2696900	10081100	12778000	17508200	7427100	4730200	3713550	2365100	3713550	2365100	69368200	51819250	9.31	5.93
15	5000	433800	12778000	2643600	10134400	12778000	17508200	7373800	4730200	3686900	2365100	3686900	2365100	73055100	54184350	9.24	5.93
16	3500	303700	9515600	2294300	7221300	9515600	12488100	5266800	2972500	2633400	1486250	2633400	1486250	75688500	55670600	6.60	3.72
17	3500	303700	9515600	2241100	7274500	9515600	12488100	5213600	2972500	2606800	1486250	2606800	1486250	78295300	57156850	6.53	3.72
18	3500	303700	9515600	2187600	7328000	9515600	12488100	5160100	2972500	2580050	1486250	2580050	1486250	80875350	58643100	6.46	3.72
19	3500	303700	9515600	2134400	7381200	9515600	12488100	5106900	2972500	2553450	1486250	2553450	1486250	83428800	60129350	6.40	3.72
20	3500	303700	9515600	2080900	7434700	9515600	12488100	5053400	2972500	2526700	1486250	2526700	1486250	85955500	61615600	6.33	3.72
21	1500	130100	4916100	1685300	3230800	4916100	5522700	2291900	606600	1145950	303300	1145950	303300	87101450	61918900	2.87	0.76
22	1500	130100	4916100	1632000	3284100	4916100	5522700	2238600	606600	1119300	303300	1119300	303300	88220750	62222200	2.80	0.76
23	1500	130100	4916100	1578600	3337500	4916100	5522700	2185200	606600	1092600	303300	1092600	303300	89313350	62525500	2.74	0.76
24	1500	130100	4916100	1525300	3390800	4916100	5522700	2131900	606600	1065950	303300	1065950	303300	90379300	62828800	2.67	0.76
25	1500	130100	4916100	1471900	3444200	4916100	5522700	2078500	606600	1039250	303300	1039250	303300	91418550	63132100	2.60	0.76
26	1500	130100	4916100	1418600	3497500	4916100	5522700	2025200	606600	1012600	303300	1012600	303300	92431150	63435400	2.54	0.76
27	1500	130100	4916100	1365200	3550900	4916100	5522700	1971800	606600	985900	303300	985900	303300	93417050	63738700	2.47	0.76
28	1500	130100	4916100	1311900	3604200	4916100	5522700	1918500	606600	959250	303300	959250	303300	94376300	64042000	2.40	0.76
29	1500	130100	4916100	1258500	3657600	4916100	5522700	1865100	606600	932550	303300	932550	303300	95308850	64345300	2.34	0.76
30	1500	130100	4916100	1205000	3711100	4916100	5522700	1811600	606600	905800	303300	905800	303300	96214650	64648600	2.27	0.76
31	1500	130100	4916100	1151800	3764300	4916100	5522700	1758400	606600	879200	303300	879200	303300	97093850	64951900	2.20	0.76
32	1500	130100	4916100	1098300	3817800	4916100	5522700	1704900	606600	852450	303300	852450	303300	97946300	65255200	2.14	0.76
33	1500	130100	4916100	1045100	3871000	4916100	5522700	1651700	606600	825850	303300	825850	303300	98772150	65558500	2.07	0.76
34	1500	130100	4916100	991600	3924500	4916100	5522700	1598200	606600	799100	303300	799100	303300	99571250	65861800	2.00	0.76
35	1500	130100	4916100	938400	3977700	4916100	5522700	1545000	606600	772500	303300	772500	303300	100343750	66155100	1.94	0.76
TOTAL	114000	9892200	341720600	68357300	273363300	341720600	400950800	127587500	59230200	63793750	29615100	100343750	66165100		AVG=	5.00	2.32

Table B-113

PROCESS 9, NONREGULATED FERTILIZER CO. ECONOMICS, 200 MW., EXISTING UNIT, 3.5% S IN COAL, 26-19-0 FERTILIZER PRODUCTION

FIXED INVESTMENT = $ 11428000
TOTAL INITIAL INVESTMENT = $ 12303000
OVERALL INTEREST RATE OF RETURN WITH PAYMENT = 0.5%
OVERALL INTEREST RATE OF RETURN WITHOUT PAYMENT = NEG

YEARS REQUIRED FOR PAYOUT WITH PAYMENT: 14.5
NO PAYOUT WITHOUT PAYMENT

YEARS AFTER POWER UNIT START	ANNUAL OPERATION KW-HR/KW	TONS/YEAR FERTILIZER	TOTAL FERTILIZER MFG. COST, $/YEAR	ALTERNATIVE WET-LIMESTONE PROCESS COST AS PAYMENT TO FERTILIZER COMPANY FOR AIR POLLUTION CONTROL, $/YEAR	NET FERTILIZER MFG COST, $/YEAR WITH PAYMENT	NET FERTILIZER MFG COST, $/YEAR WITHOUT PAYMENT	NET FERTILIZER SALES REVENUE, $/YEAR	GROSS INCOME, $/YEAR WITH PAYMENT	GROSS INCOME, $/YEAR WITHOUT PAYMENT	NET INCOME AFTER TAXES, $/YEAR WITH PAYMENT	NET INCOME AFTER TAXES, $/YEAR WITHOUT PAYMENT	CASH FLOW, $/YEAR WITH PAYMENT	CASH FLOW, $/YEAR WITHOUT PAYMENT	CUMULATIVE CASH FLOW, $ WITH PAYMENT	CUMULATIVE CASH FLOW, $ WITHOUT PAYMENT	ANNUAL RETURN ON INITIAL INVESTMENT, % WITH PAYMENT	ANNUAL RETURN ON INITIAL INVESTMENT, % WITHOUT PAYMENT
1																	
2																	
3																	
4																	
5																	
6																	
7																	
8																	
9	7000	97100	5157200	1087900	4069300	5157200	4386000	316700	(771200)	158350	(385600)	1301150	757200	1301150	757200	1.29	
10	7000	97100	5157200	1067700	4089500	5157200	4386000	296500	(771200)	148250	(385600)	1291050	757200	2592200	1514400	1.20	
11	5000	69500	4217600	947100	3270500	4217600	3162300	(108200)	(1055300)	(54100)	(527650)	1088700	615150	3680900	2129550		
12	5000	69500	4217600	927000	3290600	4217600	3162300	(128300)	(1055300)	(64150)	(527650)	1078650	615150	4759550	2744700		
13	5000	69500	4217600	906800	3310800	4217600	3162300	(148500)	(1055300)	(74250)	(527650)	1068550	615150	5828100	3359850		
14	5000	69500	4217600	886600	3331000	4217600	3162300	(168700)	(1055300)	(84350)	(527650)	1058450	615150	6886550	3975000		
15	5000	69500	4217600	866400	3351200	4217600	3162300	(188900)	(1055300)	(94450)	(527650)	1048350	615150	7934900	4590150		
16	3500	48600	3484000	762900	2721100	3484000	2225400	(495700)	(1258600)	(247850)	(629300)	894950	513500	8829850	5103650		
17	3500	48600	3484000	742800	2741200	3484000	2225400	(515800)	(1258600)	(257900)	(629300)	884900	513500	9714750	5617150		
18	3500	48600	3484000	722600	2761400	3484000	2225400	(536000)	(1258600)	(268000)	(629300)	874800	513500	10589550	6130650		
19	3500	48600	2341200	702400	1638800	2341200	2225400	586600	(115800)	293300	(57900)	293300	(57900)	10882850	6072750	2.38	
20	3500	48600	2341200	682200	1659000	2341200	2225400	566400	(115800)	283200	(57900)	283200	(57900)	11166050	6014850	2.30	
21	1500	20800	1292500	553000	739500	1292500	963000	223500	(329500)	111750	(164750)	111750	(164750)	11277800	5850100	0.91	
22	1500	20800	1292500	532800	759700	1292500	963000	203300	(329500)	101650	(164750)	101650	(164750)	11379450	5685350	0.83	
23	1500	20800	1292500	512600	779900	1292500	963000	183100	(329500)	91550	(164750)	91550	(164750)	11471000	5520600	0.74	
24	1500	20800	1292500	492400	800100	1292500	963000	162900	(329500)	81450	(164750)	81450	(164750)	11552450	5355850	0.66	
25	1500	20800	1292500	472300	820200	1292500	963000	142800	(329500)	71400	(164750)	71400	(164750)	11623850	5191100	0.58	
26	1500	20800	1292500	452100	840400	1292500	963000	122600	(329500)	61300	(164750)	61300	(164750)	11685150	5026350	0.50	
27	1500	20800	1292500	431900	860600	1292500	963000	102400	(329500)	51200	(164750)	51200	(164750)	11736350	4861600	0.42	
28	1500	20800	1292500	411700	880800	1292500	963000	82200	(329500)	41100	(164750)	41100	(164750)	11777450	4696850	0.33	
29	1500	20800	1292500	391600	900900	1292500	963000	62100	(329500)	31050	(164750)	31050	(164750)	11808500	4532100	0.25	
30	1500	20800	1292500	371400	921100	1292500	963000	41900	(329500)	20950	(164750)	20950	(164750)	11829450	4367350	0.17	
31	1500	20800	1292500	351200	941300	1292500	963000	21700	(329500)	10850	(164750)	10850	(164750)	11840300	4202600	0.09	
32	1500	20800	1292500	331000	961500	1292500	963000	1500	(329500)	750	(164750)	750	(164750)	11841050	4037850	0.01	
33	1500	20800	1292500	310900	981600	1292500	963000	(18600)	(329500)	(9300)	(164750)	(9300)	(164750)	11831750	3873100		
34	1500	20800	1292500	290700	1001800	1292500	963000	(38800)	(329500)	(19400)	(164750)	(19400)	(164750)	11812350	3708350		
35	1500	20800	1292500	270500	1022000	1292500	963000	(59000)	(329500)	(29500)	(164750)	(29500)	(164750)	11792850	3543600		
TOTAL	79000	1096700	65924300	16478500	49445800	65924300	50155500	709700	(15768800)	354850	(7884400)	11782850	3543600		AVG=	0.11	

Table B-114

PROCESS 8. NONREGULATED FERTILIZER CO. ECONOMICS, 500 MW., NEW UNIT, 2.0% S IN COAL, 26-19-0 FERTILIZER PRODUCTION

FIXED INVESTMENT = $ 15574000
TOTAL INITIAL INVESTMENT = $ 16744800
OVERALL INTEREST RATE OF RETURN WITH PAYMENT = 8.3%
OVERALL INTEREST RATE OF RETURN WITHOUT PAYMENT = NEG

YEARS REQUIRED FOR PAYOUT WITH PAYMENT: 7.8
NO PAYOUT WITHOUT PAYMENT

YEARS AFTER POWER UNIT START	ANNUAL OPERATION KW-HR/KW	TONS/YEAR FERTILIZER	TOTAL FERTILIZER MFG. COST, $/YEAR	ALTERNATIVE WET-LIMESTONE PROCESS COST AS PAYMENT TO FERTILIZER COMPANY FOR AIR POLLUTION CONTROL, $/YEAR	NET FERTILIZER MFG COST, $/YEAR		NET FERTILIZER SALES REVENUE, $/YEAR	GROSS INCOME, $/YEAR		NET INCOME AFTER TAXES, $/YEAR		CASH FLOW, $/YEAR		CUMULATIVE CASH FLOW, $		ANNUAL RETURN ON INITIAL INVESTMENT, %	
					WITH PAYMENT	WITHOUT PAYMENT		WITH PAYMENT	WITHOUT PAYMENT	WITH PAYMENT	WITHOUT PAYMENT	WITH PAYMENT	WITHOUT PAYMENT	WITH PAYMENT	WITHOUT PAYMENT	WITH PAYMENT	WITHOUT PAYMENT
1	7000	131500	6711500	1800000	4911500	6711500	5896500	985000	(815000)	492500	(407500)	2049900	1149900	2049900	1149900	2.94	
2	7000	131500	6711500	1772800	4938700	6711500	5896500	957800	(815000)	478900	(407500)	2036300	1149900	4086200	2299800	2.86	
3	7000	131500	6711500	1749100	4962400	6711500	5896500	934100	(815000)	467050	(407500)	2024450	1149900	6110650	3449700	2.79	
4	7000	131500	6711500	1718800	4992700	6711500	5896500	903800	(815000)	451900	(407500)	2009300	1149900	8119950	4599600	2.70	
5	7000	131500	6711500	1690600	5020900	6711500	5896500	875600	(815000)	437800	(407500)	1995200	1149900	10115150	5749500	2.61	
6	7000	131500	6711500	1663400	5048100	6711500	5896500	848400	(815000)	424200	(407500)	1981600	1149900	12096750	6899400	2.53	
7	7000	131500	6711500	1635900	5075600	6711500	5896500	820900	(815000)	410450	(407500)	1967850	1149900	14064600	8049300	2.45	
8	7000	131500	6711500	1608700	5102800	6711500	5896500	793700	(815000)	396850	(407500)	1954250	1149900	16018850	9199200	2.37	
9	7000	131500	6711500	1581200	5130300	6711500	5896500	766200	(815000)	383100	(407500)	1940500	1149900	17959350	10349100	2.29	
10	7000	131500	6711500	1553800	5157700	6711500	5896500	738800	(815000)	369400	(407500)	1926800	1149900	19886150	11499000	2.21	
11	5000	93900	3943300	1379800	2563500	3943300	4246200	1682700	302900	841350	151450	841350	151450	20727500	11650450	5.02	0.90
12	5000	93900	3943300	1352300	2591000	3943300	4246200	1655200	302900	827600	151450	827600	151450	21555100	11801900	4.94	0.90
13	5000	93900	3943300	1325100	2618200	3943300	4246200	1628000	302900	814000	151450	814000	151450	22369100	11953350	4.86	0.90
14	5000	93900	3943300	1297900	2645400	3943300	4246200	1600800	302900	800400	151450	800400	151450	23169500	12104800	4.78	0.90
15	5000	93900	3943300	1270400	2672900	3943300	4246200	1573300	302900	786650	151450	786650	151450	23956150	12256250	4.70	0.90
16	3500	65800	2999300	1114100	1885200	2999300	2997200	1112000	(2100)	556000	(1050)	556000	(1050)	24512150	12255200	3.32	
17	3500	65800	2999300	1086700	1912600	2999300	2997200	1084600	(2100)	542300	(1050)	542300	(1050)	25054450	12254150	3.24	
18	3500	65800	2999300	1059200	1940100	2999300	2997200	1057100	(2100)	528550	(1050)	528550	(1050)	25583000	12253100	3.16	
19	3500	65800	2999300	1032000	1967300	2999300	2997200	1029900	(2100)	514950	(1050)	514950	(1050)	26097950	12252050	3.08	
20	3500	65800	2999300	1004500	1994800	2999300	2997200	1002400	(2100)	501200	(1050)	501200	(1050)	26599150	12251000	2.99	
21	1500	28200	1655500	827100	828400	1655500	1301400	473000	(354100)	236500	(177050)	236500	(177050)	26835650	12073950	1.41	
22	1500	28200	1655500	799800	855700	1655500	1301400	445700	(354100)	222850	(177050)	222850	(177050)	27058500	11896900	1.33	
23	1500	28200	1655500	772400	883100	1655500	1301400	418300	(354100)	209150	(177050)	209150	(177050)	27267650	11719850	1.25	
24	1500	28200	1655500	745100	910400	1655500	1301400	391000	(354100)	195500	(177050)	195500	(177050)	27463150	11542800	1.17	
25	1500	28200	1655500	717700	937800	1655500	1301400	363600	(354100)	181800	(177050)	181800	(177050)	27644950	11365750	1.09	
26	1500	28200	1655500	690400	965100	1655500	1301400	336300	(354100)	168150	(177050)	168150	(177050)	27813100	11188700	1.00	
27	1500	28200	1655500	663000	992500	1655500	1301400	308900	(354100)	154450	(177050)	154450	(177050)	27967550	11011650	0.92	
28	1500	28200	1655500	635500	1020000	1655500	1301400	281400	(354100)	140700	(177050)	140700	(177050)	28108250	10834600	0.84	
29	1500	28200	1655500	608300	1047200	1655500	1301400	254200	(354100)	127100	(177050)	127100	(177050)	28235350	10657550	0.76	
30	1500	28200	1655500	580800	1074700	1655500	1301400	226700	(354100)	113350	(177050)	113350	(177050)	28348700	10480500	0.68	
31	1500	28200	1655500	553600	1101900	1655500	1301400	199500	(354100)	99750	(177050)	99750	(177050)	28448450	10303450	0.60	
32	1500	28200	1655500	526100	1129400	1655500	1301400	172000	(354100)	86000	(177050)	86000	(177050)	28534450	10126400	0.51	
33	1500	28200	1655500	498900	1156600	1655500	1301400	144800	(354100)	72400	(177050)	72400	(177050)	28606850	9949350	0.43	
34	1500	28200	1655500	471400	1184100	1655500	1301400	117300	(354100)	58650	(177050)	58650	(177050)	28665500	9772300	0.35	
35	1500	28200	1655500	444200	1211300	1655500	1301400	90100	(354100)	45050	(177050)	45050	(177050)	28710550	9595250	0.27	
TOTAL	135000	2536500	126660500	38230600	88429900	126660500	114703000	26273100	(11957500)	13136550	(5978750)	28710550	9595250		AVG=	2.24	

Table B-115

PROCESS 9, NONREGULATED FERTILIZER CO. ECONOMICS, 500 MW., NEW UNIT, 3.5% S IN COAL, 28-19-0 FERTILIZER PRODUCTION

FIXED INVESTMENT = $ 19689000
TOTAL INITIAL INVESTMENT = $ 21579500
OVERALL INTEREST RATE OF RETURN WITH PAYMENT = 12.5%
OVERALL INTEREST RATE OF RETURN WITHOUT PAYMENT = 4.0%

YEARS REQUIRED FOR PAYOUT WITH PAYMENT: 6.3
YEARS REQUIRED FOR PAYOUT WITHOUT PAYMENT: 9.6

YEARS AFTER POWER UNIT START	ANNUAL OPERATION KW-HR/ KW	TONS/YEAR FERTILIZER	TOTAL FERTILIZER MFG. COST, $/YEAR	ALTERNATIVE WET-LIMESTONE PROCESS COST AS PAYMENT TO FERTILIZER COMPANY FOR AIR POLLUTION CONTROL, $/YEAR	NET FERTILIZER MFG COST, $/YEAR		NET FERTILIZER SALES REVENUE, $/YEAR	GROSS INCOME, $/YEAR		NET INCOME AFTER TAXES, $/YEAR		CASH FLOW, $/YEAR		CUMULATIVE CASH FLOW, $		ANNUAL RETURN ON INITIAL INVESTMENT, %	
					WITH PAYMENT	WITHOUT PAYMENT		WITH PAYMENT	WITHOUT PAYMENT	WITH PAYMENT	WITHOUT PAYMENT	WITH PAYMENT	WITHOUT PAYMENT	WITH PAYMENT	WITHOUT PAYMENT	WITH PAYMENT	WITHOUT PAYMENT
1	7000	230000	9857700	2150200	7707500	9857700	10129200	2421700	271500	1210850	135750	3179750	2104650	3179750	2104650	5.61	0.63
2	7000	230000	9857700	2119600	7738100	9857700	10129200	2391100	271500	1195550	135750	3164450	2104650	6344200	4209300	5.54	0.63
3	7000	230000	9857700	2089200	7768500	9857700	10129200	2360700	271500	1180350	135750	3149250	2104650	9493450	6313950	5.47	0.63
4	7000	230000	9857700	2058700	7799000	9857700	10129200	2330200	271500	1165100	135750	3134000	2104650	12627450	8418600	5.40	0.63
5	7000	230000	9857700	2028100	7829600	9857700	10129200	2299600	271500	1149800	135750	3118700	2104650	15746150	10523250	5.33	0.63
6	7000	230000	9857700	1997500	7860200	9857700	10129200	2269000	271500	1134500	135750	3103400	2104650	18849550	12627900	5.26	0.63
7	7000	230000	9857700	1967100	7890600	9857700	10129200	2238600	271500	1119300	135750	3088200	2104650	21937750	14732550	5.19	0.63
8	7000	230000	9857700	1936600	7921100	9857700	10129200	2208100	271500	1104050	135750	3072950	2104650	25010700	16837200	5.12	0.63
9	7000	230000	9857700	1906000	7951700	9857700	10129200	2177500	271500	1088750	135750	3057650	2104650	28068350	18941850	5.05	0.63
10	7000	230000	9857700	1875600	7982100	9857700	10129200	2147100	271500	1073550	135750	3042450	2104650	31110800	21046500	4.97	0.63
11	5000	164300	5965100	1640100	4325000	5965100	7317900	2992900	1352800	1496450	676400	1496450	676400	32607250	21722900	6.93	3.13
12	5000	164300	5965100	1610000	4355100	5965100	7317900	2962800	1352800	1481400	676400	1481400	676400	34088650	22399300	6.86	3.13
13	5000	164300	5965100	1579400	4385700	5965100	7317900	2932200	1352800	1466100	676400	1466100	676400	35554750	23075700	6.79	3.13
14	5000	164300	5965100	1549000	4416100	5965100	7317900	2901800	1352800	1450900	676400	1450900	676400	37005650	23752100	6.72	3.13
15	5000	164300	5965100	1518400	4446700	5965100	7317900	2871200	1352800	1435600	676400	1435600	676400	38441250	24428500	6.65	3.13
16	3500	115000	4476100	1311600	3164500	4476100	5173900	2009400	697800	1004700	348900	1004700	348900	39445950	24777400	4.66	1.62
17	3500	115000	4476100	1281200	3194900	4476100	5173900	1979000	697800	989500	348900	989500	348900	40435450	25126300	4.59	1.62
18	3500	115000	4476100	1250600	3225500	4476100	5173900	1948400	697800	974200	348900	974200	348900	41409650	25475200	4.51	1.62
19	3500	115000	4476100	1220100	3256000	4476100	5173900	1917900	697800	958950	348900	958950	348900	42368600	25824100	4.44	1.62
20	3500	115000	4476100	1189700	3286400	4476100	5173900	1887500	697800	943750	348900	943750	348900	43312350	26173000	4.37	1.62
21	1500	49300	2385300	952200	1433100	2385300	2257000	823900	(128300)	411950	(64150)	411950	(64150)	43724300	26108850	1.91	
22	1500	49300	2385300	921600	1463700	2385300	2257000	793300	(128300)	396650	(64150)	396650	(64150)	44120950	26044700	1.84	
23	1500	49300	2385300	891100	1494200	2385300	2257000	762800	(128300)	381400	(64150)	381400	(64150)	44502350	25980550	1.77	
24	1500	49300	2385300	860700	1524600	2385300	2257000	732400	(128300)	366200	(64150)	366200	(64150)	44868550	25916400	1.70	
25	1500	49300	2385300	830100	1555200	2385300	2257000	701800	(128300)	350900	(64150)	350900	(64150)	45219450	25852250	1.63	
26	1500	49300	2385300	799500	1585800	2385300	2257000	671200	(128300)	335600	(64150)	335600	(64150)	45555050	25788100	1.56	
27	1500	49300	2385300	769200	1616100	2385300	2257000	640900	(128300)	320450	(64150)	320450	(64150)	45875500	25723950	1.48	
28	1500	49300	2385300	738400	1646900	2385300	2257000	610100	(128300)	305050	(64150)	305050	(64150)	46180550	25659800	1.41	
29	1500	49300	2385300	708100	1677200	2385300	2257000	579800	(128300)	289900	(64150)	289900	(64150)	46470450	25595650	1.34	
30	1500	49300	2385300	677400	1707900	2385300	2257000	549100	(128300)	274550	(64150)	274550	(64150)	46745000	25531500	1.27	
31	1500	49300	2385300	647100	1738200	2385300	2257000	518800	(128300)	259400	(64150)	259400	(64150)	47004400	25467350	1.20	
32	1500	49300	2385300	616500	1768800	2385300	2257000	488200	(128300)	244100	(64150)	244100	(64150)	47248500	25403200	1.13	
33	1500	49300	2385300	585900	1799400	2385300	2257000	457600	(128300)	228800	(64150)	228800	(64150)	47477300	25339050	1.06	
34	1500	49300	2385300	555600	1829700	2385300	2257000	427300	(128300)	213650	(64150)	213650	(64150)	47690950	25274900	0.99	
35	1500	49300	2385300	525000	1860300	2385300	2257000	396700	(128300)	198350	(64150)	198350	(64150)	47889300	25210750	0.92	
TOTAL	135000	4436000	186562500	45357100	141205400	186562500	197606000	56400600	11043500	28200300	5521750	47889300	25210750		AVG=	3.73	0.73

Table B 116

PROCESS 9, NONREGULATED FERTILIZER CO. ECONOMICS, 500 MW., EXISTING UNIT, 3.5% S IN COAL, 26-19-0 FERTILIZER PRODUCTION

FIXED INVESTMENT = $ 20191000
TOTAL INITIAL INVESTMENT = $ 22128700
OVERALL INTEREST RATE OF RETURN WITH PAYMENT = 11.1%
OVERALL INTEREST RATE OF RETURN WITHOUT PAYMENT = 0.8%

YEARS REQUIRED FOR PAYOUT WITH PAYMENT: 6.4
YEARS REQUIRED FOR PAYOUT WITHOUT PAYMENT: 11.3

YEARS AFTER POWER UNIT START	ANNUAL OPERATION KW-HR/KW	TONS/YEAR FERTILIZER	TOTAL FERTILIZER MFG. COST, $/YEAR	ALTERNATIVE WET-LIMESTONE PROCESS COST AS PAYMENT TO FERTILIZER COMPANY FOR AIR POLLUTION CONTROL, $/YEAR	NET FERTILIZER MFG COST, $/YEAR		NET FERTILIZER SALES REVENUE, $/YEAR	GROSS INCOME, $/YEAR		NET INCOME AFTER TAXES, $/YEAR		CASH FLOW, $/YEAR		CUMULATIVE CASH FLOW, $		ANNUAL RETURN ON INITIAL INVESTMENT, %	
					WITH PAYMENT	WITHOUT PAYMENT		WITH PAYMENT	WITHOUT PAYMENT	WITH PAYMENT	WITHOUT PAYMENT	WITH PAYMENT	WITHOUT PAYMENT	WITH PAYMENT	WITHOUT PAYMENT	WITH PAYMENT	WITHOUT PAYMENT
1																	
2																	
3																	
4	7000	235800	10240200	2261500	7978700	10240200	10375200	2396500	135000	1198250	67500	3217350	2086600	3217350	2086600	5.41	0.31
5	7000	235800	10240200	2226100	8014100	10240200	10375200	2361100	135000	1180550	67500	3199650	2086600	6417000	4173200	5.33	0.31
6	7000	235800	10240200	2191000	8049200	10240200	10375200	2326000	135000	1163000	67500	3182100	2086600	9599100	6259800	5.26	0.31
7	7000	235800	10240200	2155600	8084600	10240200	10375200	2290600	135000	1145300	67500	3164400	2086600	12763500	8346400	5.18	0.31
8	7000	235800	10240200	2120500	8119700	10240200	10375200	2255500	135000	1127750	67500	3146850	2086600	15910350	10433000	5.10	0.31
9	7000	235800	10240200	2085100	8155100	10240200	10375200	2220100	135000	1110050	67500	3129150	2086600	19039500	12519600	5.02	0.31
10	7000	235800	10240200	2050000	8190200	10240200	10375200	2185000	135000	1092500	67500	3111600	2086600	22151100	14606200	4.94	0.31
11	5000	168200	8309000	1804000	6505000	8309000	7486600	981600	(822400)	490800	(411200)	2509900	1607900	24661000	16214100	2.22	
12	5000	168200	8309000	1768900	6540100	8309000	7486600	946500	(822400)	473250	(411200)	2492350	1607900	27153350	17822000	2.14	
13	5000	168200	8309000	1733500	6575500	8309000	7486600	911100	(822400)	455550	(411200)	2474650	1607900	29628000	19429900	2.06	
14	5000	168200	6289900	1698300	4591600	6289900	7486600	2895000	1196700	1447500	598350	1447500	598350	31075500	20028250	6.54	2.70
15	5000	168200	6289900	1663000	4626900	6289900	7486600	2859700	1196700	1429850	598350	1429850	598350	32505350	20626600	6.46	2.70
16	3500	117900	4657600	1447600	3210000	4657600	5300800	2090800	643200	1045400	321600	1045400	321600	33550750	20948200	4.72	1.45
17	3500	117900	4657600	1412300	3245300	4657600	5300800	2055500	643200	1027750	321600	1027750	321600	34578500	21269800	4.64	1.45
18	3500	117900	4657600	1377100	3280500	4657600	5300800	2020300	643200	1010150	321600	1010150	321600	35588650	21591400	4.56	1.45
19	3500	117900	4657600	1341800	3315800	4657600	5300800	1985000	643200	992500	321600	992500	321600	36581150	21913000	4.49	1.45
20	3500	117900	4657600	1306600	3351000	4657600	5300800	1949800	643200	974900	321600	974900	321600	37556050	22234600	4.41	1.45
21	1500	50500	2473300	1061200	1412100	2473300	2310400	898300	(162900)	449150	(81450)	449150	(81450)	38005200	22153150	2.03	
22	1500	50500	2473300	1025900	1447400	2473300	2310400	863000	(162900)	431500	(81450)	431500	(81450)	38436700	22071700	1.95	
23	1500	50500	2473300	990700	1482600	2473300	2310400	827800	(162900)	413900	(81450)	413900	(81450)	38850600	21990250	1.87	
24	1500	50500	2473300	955400	1517900	2473300	2310400	792500	(162900)	396250	(81450)	396250	(81450)	39246850	21908800	1.79	
25	1500	50500	2473300	920200	1553100	2473300	2310400	757300	(162900)	378650	(81450)	378650	(81450)	39625500	21827350	1.71	
26	1500	50500	2473300	884900	1588400	2473300	2310400	722000	(162900)	361000	(81450)	361000	(81450)	39986500	21745900	1.63	
27	1500	50500	2473300	849700	1623600	2473300	2310400	686800	(162900)	343400	(81450)	343400	(81450)	40329900	21664450	1.55	
28	1500	50500	2473300	814300	1659000	2473300	2310400	651400	(162900)	325700	(81450)	325700	(81450)	40655600	21583000	1.47	
29	1500	50500	2473300	779200	1694100	2473300	2310400	616300	(162900)	308150	(81450)	308150	(81450)	40963750	21501550	1.39	
30	1500	50500	2473300	743800	1729500	2473300	2310400	580900	(162900)	290450	(81450)	290450	(81450)	41254200	21420100	1.31	
31	1500	50500	2473300	708700	1764600	2473300	2310400	545800	(162900)	272900	(81450)	272900	(81450)	41527100	21338650	1.23	
32	1500	50500	2473300	673300	1800000	2473300	2310400	510400	(162900)	255200	(81450)	255200	(81450)	41782300	21257200	1.15	
33	1500	50500	2473300	638200	1835100	2473300	2310400	475300	(162900)	237650	(81450)	237650	(81450)	42019950	21175750	1.07	
34	1500	50500	2473300	602800	1870500	2473300	2310400	439900	(162900)	219950	(81450)	219950	(81450)	42239900	21094300	0.99	
35	1500	50500	2473300	567700	1905600	2473300	2310400	404800	(162900)	202400	(81450)	202400	(81450)	42442300	21012850	0.91	
TOTAL	114000	3838600	169575700	42858900	126716800	169575700	171219400	44502600	1643700	22251300	821850	42442300	21012850		AVG=	3.14	0.12

Table B-117

PROCESS 9, NONREGULATED FERTILIZER CO. ECONOMICS, 500 MW., NEW UNIT, 5.0% S IN COAL, 26-19-0 FERTILIZER PRODUCTION

FIXED INVESTMENT = $ 23525000
TOTAL INITIAL INVESTMENT = $ 25918100
OVERALL INTEREST RATE OF RETURN WITH PAYMENT = 16.5%
OVERALL INTEREST RATE OF RETURN WITHOUT PAYMENT = 9.6%

YEARS REQUIRED FOR PAYOUT WITH PAYMENT: 5.2
YEARS REQUIRED FOR PAYOUT WITHOUT PAYMENT: 7.2

YEARS AFTER POWER UNIT START	ANNUAL OPERATION KW-HR/KW	TONS/YEAR FERTILIZER	TOTAL FERTILIZER MFG. COST, $/YEAR	ALTERNATIVE WET-LIMESTONE PROCESS COST AS PAYMENT TO FERTILIZER COMPANY FOR AIR POLLUTION CONTROL, $/YEAR	NET FERTILIZER MFG COST, $/YEAR		NET FERTILIZER SALES REVENUE, $/YEAR	GROSS INCOME, $/YEAR		NET INCOME AFTER TAXES, $/YEAR		CASH FLOW, $/YEAR		CUMULATIVE CASH FLOW, $		ANNUAL RETURN ON INITIAL INVESTMENT, %	
					WITH PAYMENT	WITHOUT PAYMENT		WITH PAYMENT	WITHOUT PAYMENT	WITH PAYMENT	WITHOUT PAYMENT	WITH PAYMENT	WITHOUT PAYMENT	WITH PAYMENT	WITHOUT PAYMENT	WITH PAYMENT	WITHOUT PAYMENT
1	7000	328600	12414100	2506500	9907600	12414100	14264500	4356900	1850400	2178450	925200	4530950	3277700	4530950	3277700	8.41	3.57
2	7000	328600	12414100	2473000	9941100	12414100	14264500	4323400	1850400	2161700	925200	4514200	3277700	9045150	6555400	8.34	3.57
3	7000	328600	12414100	2439300	9974800	12414100	14264500	4289700	1850400	2144850	925200	4497350	3277700	13542500	9833100	8.28	3.57
4	7000	328600	12414100	2405800	10008300	12414100	14264500	4256200	1850400	2128100	925200	4480600	3277700	18023100	13110800	8.21	3.57
5	7000	328600	12414100	2372100	10042000	12414100	14264500	4222500	1850400	2111250	925200	4463750	3277700	22486850	16388500	8.15	3.57
6	7000	328600	12414100	2338600	10075500	12414100	14264500	4189000	1850400	2094500	925200	4447000	3277700	26933850	19666200	8.08	3.57
7	7000	328600	12414100	2304900	10109200	12414100	14264500	4155300	1850400	2077650	925200	4430150	3277700	31364000	22943900	8.02	3.57
8	7000	328600	12414100	2271500	10142600	12414100	14264[illegible]	4121900	1850400	2060950	925200	4413450	3277700	35777450	26221600	7.95	3.57
9	7000	328600	12414100	2238000	10176100	12414100	14264[illegible]	4088400	1850400	2044200	925200	4396700	3277700	40174150	29499300	7.89	3.57
10	7000	328600	12414100	2204300	10209800	12414100	142[illegible]	4054700	1850400	2027350	925200	4379850	3277700	44554000	32777000	7.82	3.57
11	5000	234700	7581600	1903900	5677700	7581600	1032[illegible]	4651400	2747500	2325700	1373750	2325700	1373750	46879700	34150750	8.97	5.30
12	5000	234700	7581600	1870200	5711400	7581600	1032[illegible]	4617700	2747500	2308850	1373750	2308850	1373750	49188550	35524500	8.91	5.30
13	5000	234700	7581600	1836700	5744900	7581600	103291[illegible]	4584200	2747500	2292100	1373750	2292100	1373750	51480650	36898250	8.84	5.30
14	5000	234700	7581600	1803000	5778600	7581600	10329100	4550500	2747500	2275250	1373750	2275250	1373750	53755900	38272000	8.78	5.30
15	5000	234700	7581600	1769500	5812100	7581600	10329100	4517000	2747500	2258500	1373750	2258500	1373750	56014400	39645750	8.71	5.30
16	3500	164300	5666200	1512100	4154100	5666200	7317900	3163800	1651700	1581900	825850	1581900	825850	57596300	40471600	6.10	3.19
17	3500	164300	5666200	1478400	4187800	5666200	7317900	3130100	1651700	1565050	825850	1565050	825850	59161350	41297450	6.04	3.19
18	3500	164300	5666200	1444900	4221300	5666200	7317900	3096600	1651700	1548300	825850	1548300	825850	60709650	42123300	5.97	3.19
19	3500	164300	5666200	1411300	4254900	5666200	7317900	3063000	1651700	1531500	825850	1531500	825850	62241150	42949150	5.91	3.19
20	3500	164300	5666200	1377800	4288400	5666200	7317900	3029500	1651700	1514750	825850	1514750	825850	63755900	43775000	5.84	3.19
21	1500	70400	2986400	1078200	1908200	2986400	3201800	1293600	215400	646800	107700	646800	107700	64402700	43882700	2.50	0.42
22	1500	70400	2986400	1044700	1941700	2986400	3201800	1260100	215400	630050	107700	630050	107700	65032750	43990400	2.43	0.42
23	1500	70400	2986400	1011900	1974500	2986400	3201800	1227300	215400	613650	107700	613650	107700	65646400	44098100	2.37	0.42
24	1500	70400	2986400	977500	2008900	2986400	3201800	1192900	215400	596450	107700	596450	107700	66242850	44205800	2.30	0.42
25	1500	70400	2986400	944000	2042400	2986400	3201800	1159400	215400	579700	107700	579700	107700	66822550	44313500	2.24	0.42
26	1500	70400	2986400	910300	2076100	2986400	3201800	1125700	215400	562850	107700	562850	107700	67385400	44421200	2.17	0.42
27	1500	70400	2986400	876800	2109600	2986400	3201800	1092200	215400	546100	107700	546100	107700	67931500	44528900	2.11	0.42
28	1500	70400	2986400	843100	2143300	2986400	3201800	1058500	215400	529250	107700	529250	107700	68460750	44636600	2.04	0.42
29	1500	70400	2986400	809600	2176800	2986400	3201800	1025000	215400	512500	107700	512500	107700	68973250	44744300	1.98	0.42
30	1500	70400	2986400	776200	2210200	2986400	3201800	991600	215400	495800	107700	495800	107700	69469050	44852000	1.91	0.42
31	1500	70400	2986400	742500	2243900	2986400	3201800	957900	215400	478950	107700	478950	107700	69948000	44959700	1.85	0.42
32	1500	70400	2986400	708800	2277600	2986400	3201800	924200	215400	462100	107700	462100	107700	70410100	45067400	1.78	0.42
33	1500	70400	2986400	675300	2311100	2986400	3201800	890700	215400	445350	107700	445350	107700	70855450	45175100	1.72	0.42
34	1500	70400	2986400	641800	2344600	2986400	3201800	857200	215400	428600	107700	428600	107700	71284050	45282800	1.65	0.42
35	1500	70400	2986400	608100	2378300	2986400	3201800	823500	215400	411750	107700	411750	107700	71695800	45390500	1.59	0.42
TOTAL	135000	6337000	235176000	52610600	182565400	235176000	278907000	96341600	43731000	48170800	21865500	71695800	45390500		AVG=	5.31	2.41

Table B-118

PROCESS B. NONREGULATED FERTILIZER CO. ECONOMICS. 1000 MW., NEW UNIT, 3.5% S IN COAL, 26-19-0 FERTILIZER PRODUCTION

FIXED INVESTMENT = $ 31000000
TOTAL INITIAL INVESTMENT = $ 34244200
OVERALL INTEREST RATE OF RETURN WITH PAYMENT = 17.3%
OVERALL INTEREST RATE OF RETURN WITHOUT PAYMENT = 10.5%

YEARS REQUIRED FOR PAYOUT WITH PAYMENT: 5.1
YEARS REQUIRED FOR PAYOUT WITHOUT PAYMENT: 6.9

YEARS AFTER POWER UNIT START	ANNUAL OPERATION KW-HR/KW	TONS/YEAR FERTILIZER	TOTAL FERTILIZER MFG. COST, $/YEAR	ALTERNATIVE WET-LIMESTONE PROCESS COST AS PAYMENT TO FERTILIZER COMPANY FOR AIR POLLUTION CONTROL, $/YEAR	NET FERTILIZER MFG COST, $/YEAR		NET FERTILIZER SALES REVENUE, $/YEAR	GROSS INCOME, $/YEAR		NET INCOME AFTER TAXES, $/YEAR		CASH FLOW, $/YEAR		CUMULATIVE CASH FLOW, $		ANNUAL RETURN ON INITIAL INVESTMENT, %	
					WITH PAYMENT	WITHOUT PAYMENT		WITH PAYMENT	WITHOUT PAYMENT	WITH PAYMENT	WITHOUT PAYMENT	WITH PAYMENT	WITHOUT PAYMENT	WITH PAYMENT	WITHOUT PAYMENT	WITH PAYMENT	WITHOUT PAYMENT
1	7000	444000	16209400	3362400	12847000	16209400	18994300	6147300	2784900	3073650	1392450	6173650	4492450	6173650	4492450	8.98	4.07
2	7000	444000	16209400	3317000	12892400	16209400	18994300	6101900	2784900	3050950	1392450	6150950	4492450	12324600	8984900	8.91	4.07
3	7000	444000	16209400	3271900	12937500	16209400	18994300	6056800	2784900	3028400	1392450	6128400	4492450	18453000	13477350	8.84	4.07
4	7000	444000	16209400	3226500	12982900	16209400	18994300	6011400	2784900	3005700	1392450	6105700	4492450	24558700	17969800	8.78	4.07
5	7000	444000	16209400	3181200	13028200	16209400	18994300	5966100	2784900	2983050	1392450	6083050	4492450	30641750	22462250	8.71	4.07
6	7000	444000	16209400	3135800	13073600	16209400	18994300	5920700	2784900	2960350	1392450	6060350	4492450	36702100	26954700	8.64	4.07
7	7000	444000	16209400	3090700	13118700	16209400	18994300	5875600	2784900	2937800	1392450	6037800	4492450	42739900	31447150	8.58	4.07
8	7000	444000	16209400	3045400	13164000	16209400	18994300	5830300	2784900	2915150	1392450	6015150	4492450	48755050	35939600	8.51	4.07
9	7000	444000	16209400	3000000	13209400	16209400	18994300	5784900	2784900	2892450	1392450	5992450	4492450	54747500	40432050	8.45	4.07
10	7000	444000	16209400	2954900	13254500	16209400	18994300	5739800	2784900	2869900	1392450	5969900	4492450	60717400	44924500	8.38	4.07
11	5000	318000	9864200	2565100	7299100	9864200	13829800	6530700	3965600	3265350	1982800	3265350	1982800	63982750	46907300	9.54	5.79
12	5000	318000	9864200	2519800	7344400	9864200	13829800	6485400	3965600	3242700	1982800	3242700	1982800	67225450	48890100	9.47	5.79
13	5000	318000	9864200	2474500	7389700	9864200	13829800	6440100	3965600	3220050	1982800	3220050	1982800	70445500	50872900	9.40	5.79
14	5000	318000	9864200	2429300	7434900	9864200	13829800	6394900	3965600	3197450	1982800	3197450	1982800	73642950	52855700	9.34	5.79
15	5000	318000	9864200	2384000	7480200	9864200	13829800	6349600	3965600	3174800	1982800	3174800	1982800	76817750	54838500	9.27	5.79
16	3500	222000	7361000	2053500	5307500	7361000	9792400	4484900	2431400	2242450	1215700	2242450	1215700	79060200	56054200	6.55	3.55
17	3500	222000	7361000	2008400	5352600	7361000	9792400	4439800	2431400	2219900	1215700	2219900	1215700	81280100	57269900	6.48	3.55
18	3500	222000	7361000	1963100	5397900	7361000	9792400	4394500	2431400	2197250	1215700	2197250	1215700	83477350	58485600	6.42	3.55
19	3500	222000	7361000	1917700	5443300	7361000	9792400	4349100	2431400	2174550	1215700	2174550	1215700	85651900	59701300	6.35	3.55
20	3500	222000	7361000	1872400	5488600	7361000	9792400	4303800	2431400	2151900	1215700	2151900	1215700	87803800	60917000	6.28	3.55
21	1500	95200	3867400	1496500	2370900	3867400	4304900	1934000	437500	967000	218750	967000	218750	88770800	61135750	2.82	0.64
22	1500	95200	3867400	1451200	2416200	3867400	4304900	1888700	437500	944350	218750	944350	218750	89715150	61354500	2.76	0.64
23	1500	95200	3867400	1405800	2461600	3867400	4304900	1843300	437500	921650	218750	921650	218750	90636800	61573250	2.69	0.64
24	1500	95200	3867400	1360700	2506700	3867400	4304900	1798200	437500	899100	218750	899100	218750	91535900	61792000	2.63	0.64
25	1500	95200	3867400	1315400	2552000	3867400	4304900	1752900	437500	876450	218750	876450	218750	92412350	62010750	2.56	0.64
26	1500	95200	3867400	1270000	2597400	3867400	4304900	1707500	437500	853750	218750	853750	218750	93266100	62229500	2.49	0.64
27	1500	95200	3867400	1224700	2642700	3867400	4304900	1662200	437500	831100	218750	831100	218750	94097200	62448250	2.43	0.64
28	1500	95200	3867400	1179500	2687900	3867400	4304900	1617000	437500	808500	218750	808500	218750	94905700	62667000	2.36	0.64
29	1500	95200	3867400	1134200	2733200	3867400	4304900	1571700	437500	785850	218750	785850	218750	95691550	62885750	2.29	0.64
30	1500	95200	3867400	1088800	2778600	3867400	4304900	1526300	437500	763150	218750	763150	218750	96454700	63104500	2.23	0.64
31	1500	95200	3867400	1043700	2823700	3867400	4304900	1481200	437500	740600	218750	740600	218750	97195300	63323250	2.16	0.64
32	1500	95200	3867400	998400	2869000	3867400	4304900	1435900	437500	717950	218750	717950	218750	97913250	63542000	2.10	0.64
33	1500	95200	3867400	953000	2914400	3867400	4304900	1390500	437500	695250	218750	695250	218750	98608500	63760750	2.03	0.64
34	1500	95200	3867400	907700	2959700	3867400	4304900	1345200	437500	672600	218750	672600	218750	99281100	63979500	1.96	0.64
35	1500	95200	3867400	862500	3004900	3867400	4304900	1300000	437500	650000	218750	650000	218750	99931100	64198250	1.90	0.64
TOTAL	135000	8568000	306231000	71465700	234765300	306231000	372627500	137862200	66396500	68931100	33198250	99931100	64198250		AVG=	5.75	2.77

Table B-119

PROCESS A, NONREGULATED FERTILIZER CO. ECONOMICS, 1000 MW., EXISTING UNIT, 3.5% S IN COAL, 26-19-0 FERTILIZER PRODUCTION

FIXED INVESTMENT = $ 32904000
TOTAL INITIAL INVESTMENT = $ 36262800
OVERALL INTEREST RATE OF RETURN WITH PAYMENT = 15.1%
OVERALL INTEREST RATE OF RETURN WITHOUT PAYMENT = 7.5%

YEARS REQUIRED FOR PAYOUT WITH PAYMENT: 5.3
YEARS REQUIRED FOR PAYOUT WITHOUT PAYMENT: 7.5

YEARS AFTER POWER UNIT START	ANNUAL OPERATION KW-HR/ KW	TONS/YEAR FERTILIZER	TOTAL FERTILIZER MFG. COST, $/YEAR	ALTERNATIVE WET-LIMESTONE PROCESS COST AS PAYMENT TO FERTILIZER COMPANY FOR AIR POLLUTION CONTROL, $/YEAR	NET FERTILIZER MFG COST, $/YEAR WITH PAYMENT	NET FERTILIZER MFG COST, $/YEAR WITHOUT PAYMENT	NET FERTILIZER SALES REVENUE, $/YEAR	GROSS INCOME, $/YEAR WITH PAYMENT	GROSS INCOME, $/YEAR WITHOUT PAYMENT	NET INCOME AFTER TAXES, $/YEAR WITH PAYMENT	NET INCOME AFTER TAXES, $/YEAR WITHOUT PAYMENT	CASH FLOW, $/YEAR WITH PAYMENT	CASH FLOW, $/YEAR WITHOUT PAYMENT	CUMULATIVE CASH FLOW, $ WITH PAYMENT	CUMULATIVE CASH FLOW, $ WITHOUT PAYMENT	ANNUAL RETURN ON INITIAL INVESTMENT, % WITH PAYMENT	ANNUAL RETURN ON INITIAL INVESTMENT, % WITHOUT PAYMENT
1																	
2																	
3																	
4	7000	460000	17332900	3587300	13745600	17332900	19642000	5896400	2309100	2948200	1154550	6238600	4444950	6238600	4444950	8.13	3.18
5	7000	460000	17332900	3533800	13799100	17332900	19642000	5842900	2309100	2921450	1154550	6211850	4444950	12450450	8889900	8.06	3.18
6	7000	460000	17332900	3480600	13852300	17332900	19642000	5789700	2309100	2894850	1154550	6185250	4444950	18635700	13334850	7.98	3.18
7	7000	460000	17332900	3427200	13905700	17332900	19642000	5736300	2309100	2868150	1154550	6158550	4444950	24794250	17779800	7.91	3.18
8	7000	460000	17332900	3373900	13959000	17332900	19642000	5683000	2309100	2841500	1154550	6131900	4444950	30926150	22224750	7.84	3.18
9	7000	460000	17332900	3319900	14013000	17332900	19642000	5629000	2309100	2814500	1154550	6104900	4444950	37031050	26669700	7.76	3.18
10	7000	460000	17332900	3267200	14065700	17332900	19642000	5576300	2309100	2788150	1154550	6078550	4444950	43109600	31114650	7.69	3.18
11	5000	328600	13854800	2857000	10997800	13854800	14264500	3266700	409700	1633350	204850	4923750	3495250	48033350	34609900	4.50	0.56
12	5000	328600	13854800	2803800	11051000	13854800	14264500	3213500	409700	1606750	204850	4897150	3495250	52930500	38105150	4.43	0.56
13	5000	328600	13854800	2750300	11104500	13854800	14264500	3160000	409700	1580000	204850	4870400	3495250	57800900	41600400	4.36	0.56
14	5000	328600	10564400	2696900	7867500	10564400	14264500	6397000	3700100	3198500	1850050	3198500	1850050	60999400	43450450	8.82	5.10
15	5000	328600	10564400	2643600	7920800	10564400	14264500	6343700	3700100	3171850	1850050	3171850	1850050	64171250	45300500	8.75	5.10
16	3500	230000	7881100	2294300	5586800	7881100	10129200	4542400	2248100	2271200	1124050	2271200	1124050	66442450	46424550	6.26	3.10
17	3500	230000	7881100	2241100	5640000	7881100	10129200	4489200	2248100	2244600	1124050	2244600	1124050	68687050	47548600	6.19	3.10
18	3500	230000	7881100	2187600	5693500	7881100	10129200	4435700	2248100	2217850	1124050	2217850	1124050	70904900	48672650	6.12	3.10
19	3500	230000	7881100	2134400	5746700	7881100	10129200	4382500	2248100	2191250	1124050	2191250	1124050	73096150	49796700	6.04	3.10
20	3500	230000	7881100	2080900	5800200	7881100	10129200	4329000	2248100	2164500	1124050	2164500	1124050	75260650	50920750	5.97	3.10
21	1500	98500	4136800	1685300	2451500	4136800	4448300	1996800	311500	998400	155750	998400	155750	76259050	51076500	2.75	0.43
22	1500	98500	4136800	1632000	2504800	4136800	4448300	1943500	311500	971750	155750	971750	155750	77230800	51232250	2.68	0.43
23	1500	98500	4136800	1578600	2558200	4136800	4448300	1890100	311500	945050	155750	945050	155750	78175850	51388000	2.61	0.43
24	1500	98500	4136800	1525300	2611500	4136800	4448300	1836800	311500	918400	155750	918400	155750	79094250	51543750	2.53	0.43
25	1500	98500	4136800	1471900	2664900	4136800	4448300	1783400	311500	891700	155750	891700	155750	79985950	51699500	2.46	0.43
26	1500	98500	4136800	1418600	2718200	4136800	4448300	1730100	311500	865050	155750	865050	155750	80851000	51855250	2.39	0.43
27	1500	98500	4136800	1365200	2771600	4136800	4448300	1676700	311500	838350	155750	838350	155750	81689350	52011000	2.31	0.43
28	1500	98500	4136800	1311900	2824900	4136800	4448300	1623400	311500	811700	155750	811700	155750	82501050	52166750	2.24	0.43
29	1500	98500	4136800	1258500	2878300	4136800	4448300	1570000	311500	785000	155750	785000	155750	83286050	52322500	2.16	0.43
30	1500	98500	4136800	1205000	2931800	4136800	4448300	1516500	311500	758250	155750	758250	155750	84044300	52478250	2.09	0.43
31	1500	98500	4136800	1151800	2985000	4136800	4448300	1463300	311500	731650	155750	731650	155750	84775950	52634000	2.02	0.43
32	1500	98500	4136800	1098300	3038500	4136800	4448300	1409800	311500	704900	155750	704900	155750	85480850	52789750	1.94	0.43
33	1500	98500	4136800	1045100	3091700	4136800	4448300	1356600	311500	678300	155750	678300	155750	86159150	52945500	1.87	0.43
34	1500	98500	4136800	991600	3145200	4136800	4448300	1303100	311500	651550	155750	651550	155750	86810700	53101250	1.80	0.43
35	1500	98500	4136800	938400	3198400	4136800	4448300	1249900	311500	624950	155750	624950	155750	87435650	53257000	1.72	0.43
TOTAL	114000	7490500	285481000	68357300	217123700	285481000	326187000	109063300	40706000	54531650	20353000	87435650	53257000		AVG=	4.70	1.75

Table B-120

PROCESS C. NONREGULATED FERTILIZER CO. ECONOMICS. 200 MW., EXISTING UNIT, 3.5% S IN COAL, 19-14-0 FERTILIZER PRODUCTION

FIXED INVESTMENT = $ 9539500
TOTAL INITIAL INVESTMENT = $ 10195500
OVERALL INTEREST RATE OF RETURN WITH PAYMENT = NEG
OVERALL INTEREST RATE OF RETURN WITHOUT PAYMENT = NEG

NO PAYOUT WITH PAYMENT
NO PAYOUT WITHOUT PAYMENT

YEARS AFTER POWER UNIT START	ANNUAL OPERATION KW-HR/KW	TONS/YEAR FERTILIZER	TOTAL FERTILIZER MFG. COST, $/YEAR	ALTERNATIVE WET-LIMESTONE PROCESS COST AS PAYMENT TO FERTILIZER COMPANY FOR AIR POLLUTION CONTROL, $/YEAR	NET FERTILIZER MFG COST, $/YEAR WITH PAYMENT	NET FERTILIZER MFG COST, $/YEAR WITHOUT PAYMENT	NET FERTILIZER SALES REVENUE, $/YEAR	GROSS INCOME, $/YEAR WITH PAYMENT	GROSS INCOME, $/YEAR WITHOUT PAYMENT	NET INCOME AFTER TAXES, $/YEAR WITH PAYMENT	NET INCOME AFTER TAXES, $/YEAR WITHOUT PAYMENT	CASH FLOW, $/YEAR WITH PAYMENT	CASH FLOW, $/YEAR WITHOUT PAYMENT	CUMULATIVE CASH FLOW, $ WITH PAYMENT	CUMULATIVE CASH FLOW, $ WITHOUT PAYMENT	ANNUAL RETURN ON INITIAL INVESTMENT, % WITH PAYMENT	ANNUAL RETURN ON INITIAL INVESTMENT, % WITHOUT PAYMENT
1																	
2																	
3																	
4																	
5																	
6																	
7																	
8																	
9	7000	56700	3868200	1087900	2780300	3868200	1987300	(793000)	(1880900)	(396500)	(940450)	562450	18500	562450	18500		
10	7000	56700	3868200	1067700	2800500	3868200	1987300	(813200)	(1880900)	(406600)	(940450)	552350	18500	1114800	37000		
11	5000	40500	3217000	947100	2269900	3217000	1428400	(841500)	(1788600)	(420750)	(894300)	538200	64650	1653000	101650		
12	5000	40500	3217000	927000	2290000	3217000	1428400	(861600)	(1788600)	(430800)	(894300)	528150	64650	2181150	166300		
13	5000	40500	3217000	906800	2310200	3217000	1428400	(881800)	(1788600)	(440900)	(894300)	518050	64650	2699200	230950		
14	5000	40500	3217000	886600	2330400	3217000	1428400	(902000)	(1788600)	(451000)	(894300)	507950	64650	3207150	295600		
15	5000	40500	3217000	866400	2350600	3217000	1428400	(922200)	(1788600)	(461100)	(894300)	497850	64650	3705000	360250		
16	3500	28400	2704000	763000	1941000	2704000	1007300	(933700)	(1696700)	(466850)	(848350)	492100	110600	4197100	470850		
17	3500	28400	2704000	742800	1961200	2704000	1007300	(953900)	(1696700)	(476950)	(848350)	482000	110600	4679100	581450		
18	3500	28400	2704000	722600	1981400	2704000	1007300	(974100)	(1696700)	(487050)	(848350)	471900	110600	5151000	692050		
19	3500	28400	1745000	702400	1042600	1745000	1007300	(35300)	(737700)	(17650)	(368850)	(17650)	(368850)	5133350	323200		
20	3500	28400	1745000	682200	1062800	1745000	1007300	(55500)	(737700)	(27750)	(368850)	(27750)	(368850)	5105600	(45650)		
21	1500	12200	995800	553000	442800	995800	437000	(5800)	(558800)	(2900)	(279400)	(2900)	(279400)	5102700	(325050)		
22	1500	12200	995800	532800	463000	995800	437000	(26000)	(558800)	(13000)	(279400)	(13000)	(279400)	5089700	(604450)		
23	1500	12200	995800	512600	483200	995800	437000	(46200)	(558800)	(23100)	(279400)	(23100)	(279400)	5066600	(883850)		
24	1500	12200	995800	492400	503400	995800	437000	(66400)	(558800)	(33200)	(279400)	(33200)	(279400)	5033400	(1163250)		
25	1500	12200	995800	472300	523500	995800	437000	(86500)	(558800)	(43250)	(279400)	(43250)	(279400)	4990150	(1442650)		
26	1500	12200	995800	452100	543700	995800	437000	(106700)	(558800)	(53350)	(279400)	(53350)	(279400)	4936800	(1722050)		
27	1500	12200	995800	431900	563900	995800	437000	(126900)	(558800)	(63450)	(279400)	(63450)	(279400)	4873350	(2001450)		
28	1500	12200	995800	411700	584100	995800	437000	(147100)	(558800)	(73550)	(279400)	(73550)	(279400)	4799800	(2280850)		
29	1500	12200	995800	391600	604200	995800	437000	(167200)	(558800)	(83600)	(279400)	(83600)	(279400)	4716200	(2560250)		
30	1500	12200	995800	371400	624400	995800	437000	(187400)	(558800)	(93700)	(279400)	(93700)	(279400)	4622500	(2839650)		
31	1500	12200	995800	351200	644600	995800	437000	(207600)	(558800)	(103800)	(279400)	(103800)	(279400)	4518700	(3119050)		
32	1500	12200	995800	331000	664800	995800	437000	(227800)	(558800)	(113900)	(279400)	(113900)	(279400)	4404800	(3398450)		
33	1500	12200	995800	310900	684900	995800	437000	(247900)	(558800)	(123950)	(279400)	(123950)	(279400)	4280850	(3677850)		
34	1500	12200	995800	290700	705100	995800	437000	(268100)	(558800)	(134050)	(279400)	(134050)	(279400)	4146800	(3957250)		
35	1500	12200	995800	270500	725300	995800	437000	(288300)	(558800)	(144150)	(279400)	(144150)	(279400)	4002650	(4236650)		
TOTAL	79000	640900	50360400	16478500	33881900	50360400	22708100	(11173800)	(27652300)	(5586900)	(13826150)	4002600	(4236650)		NEG		

Table B-121

PROCESS C. NONREGULATED FERTILIZER CO. ECONOMICS, 500 MW., NEW UNIT, 2.0% S IN COAL, 19-14-0 FERTILIZER PRODUCTION

FIXED INVESTMENT = $ 13057300
TOTAL INITIAL INVESTMENT = $ 13837300
OVERALL INTEREST RATE OF RETURN WITH PAYMENT = NEG
OVERALL INTEREST RATE OF RETURN WITHOUT PAYMENT = NEG

NO PAYOUT WITH PAYMENT
NO PAYOUT WITHOUT PAYMENT

YEARS AFTER POWER UNIT START	ANNUAL OPERATION KW-HR/ KW	TONS/YEAR FERTILIZER	TOTAL FERTILIZER MFG. COST, $/YEAR	ALTERNATIVE WET-LIMESTONE PROCESS COST AS PAYMENT TO FERTILIZER COMPANY FOR AIR POLLUTION CONTROL, $/YEAR	NET FERTILIZER MFG COST, $/YEAR		NET FERTILIZER SALES REVENUE, $/YEAR	GROSS INCOME, $/YEAR		NET INCOME AFTER TAXES, $/YEAR		CASH FLOW, $/YEAR		CUMULATIVE CASH FLOW, $		ANNUAL RETURN ON INITIAL INVESTMENT, %	
					WITH PAYMENT	WITHOUT PAYMENT		WITH PAYMENT	WITHOUT PAYMENT	WITH PAYMENT	WITHOUT PAYMENT	WITH PAYMENT	WITHOUT PAYMENT	WITH PAYMENT	WITHOUT PAYMENT	WITH PAYMENT	WITHOUT PAYMENT
1	7000	76600	4980700	1800000	3180700	4980700	2667200	(513500)	(2313500)	(256750)	(1156750)	1048980	148980	1048980	148980		
2	7000	76600	4980700	1772800	3207900	4980700	2667200	(540700)	(2313500)	(270350)	(1156750)	1035380	148980	2084360	297960		
3	7000	76600	4980700	1749100	3231600	4980700	2667200	(564400)	(2313500)	(282200)	(1156750)	1023530	148980	3107890	446940		
4	7000	76600	4980700	1718800	3261900	4980700	2667200	(594700)	(2313500)	(297350)	(1156750)	1008380	148980	4116270	595920		
5	7000	76600	4980700	1690600	3290100	4980700	2667200	(622900)	(2313500)	(311450)	(1156750)	994280	148980	5110550	744900		
6	7000	76600	4980700	1663400	3317300	4980700	2667200	(650100)	(2313500)	(325050)	(1156750)	980680	148980	6091230	893880		
7	7000	76600	4980700	1635900	3344800	4980700	2667200	(677600)	(2313500)	(338800)	(1156750)	966930	148980	7058160	1042860		
8	7000	76600	4980700	1608700	3372000	4980700	2667200	(704800)	(2313500)	(352400)	(1156750)	953330	148980	8011490	1191840		
9	7000	76600	4980700	1581200	3399500	4980700	2667200	(732300)	(2313500)	(366150)	(1156750)	939580	148980	8951070	1340820		
10	7000	76600	4980700	1553800	3426900	4980700	2667200	(759700)	(2313500)	(379850)	(1156750)	925880	148980	9876950	1489800		
11	5000	54700	2850300	1379800	1470500	2850300	1917800	447300	(932500)	223650	(466250)	223650	(466250)	10100600	1023550	1.62	
12	5000	54700	2850300	1352300	1498000	2850300	1917800	419800	(932500)	209900	(466250)	209900	(466250)	10310500	557300	1.52	
13	5000	54700	2850300	1325100	1525200	2850300	1917800	392600	(932500)	196300	(466250)	196300	(466250)	10506800	91050	1.42	
14	5000	54700	2850300	1297900	1552400	2850300	1917800	365400	(932500)	182700	(466250)	182700	(466250)	10689500	(375200)	1.32	
15	5000	54700	2850300	1270400	1579900	2850300	1917800	337900	(932500)	168950	(466250)	168950	(466250)	10858450	(841450)	1.22	
16	3500	38300	2201500	1114100	1087400	2201500	1352000	264600	(849500)	132300	(424750)	132300	(424750)	10990750	(1266200)	0.96	
17	3500	38300	2201500	1086700	1114800	2201500	1352000	237200	(849500)	118600	(424750)	118600	(424750)	11109350	(1690950)	0.86	
18	3500	38300	2201500	1059200	1142300	2201500	1352000	209700	(849500)	104850	(424750)	104850	(424750)	11214200	(2115700)	0.76	
19	3500	38300	2201500	1032000	1169500	2201500	1352000	182500	(849500)	91250	(424750)	91250	(424750)	11305450	(2540450)	0.66	
20	3500	38300	2201500	1004500	1197000	2201500	1352000	155000	(849500)	77500	(424750)	77500	(424750)	11382950	(2965200)	0.56	
21	1500	16400	1258700	827100	431600	1258700	585500	153900	(673200)	76950	(336600)	76950	(336600)	11459900	(3301800)	0.56	
22	1500	16400	1258700	799800	458900	1258700	585500	126600	(673200)	63300	(336600)	63300	(336600)	11523200	(3638400)	0.46	
23	1500	16400	1258700	772400	486300	1258700	585500	99200	(673200)	49600	(336600)	49600	(336600)	11572800	(3975000)	0.36	
24	1500	16400	1258700	745100	513600	1258700	585500	71900	(673200)	35950	(336600)	35950	(336600)	11608750	(4311600)	0.26	
25	1500	16400	1258700	717700	541000	1258700	585500	44500	(673200)	22250	(336600)	22250	(336600)	11631000	(4648200)	0.16	
26	1500	16400	1258700	690400	568300	1258700	585500	17200	(673200)	8600	(336600)	8600	(336600)	11639600	(4984800)	0.06	
27	1500	16400	1258700	663000	595700	1258700	585500	(10200)	(673200)	(5100)	(336600)	(5100)	(336600)	11634500	(5321400)		
28	1500	16400	1258700	635500	623200	1258700	585500	(37700)	(673200)	(18850)	(336600)	(18850)	(336600)	11615650	(5658000)		
29	1500	16400	1258700	608300	650400	1258700	585500	(64900)	(673200)	(32450)	(336600)	(32450)	(336600)	11583200	(5994600)		
30	1500	16400	1258700	580800	677900	1258700	585500	(92400)	(673200)	(46200)	(336600)	(46200)	(336600)	11537000	(6331200)		
31	1500	16400	1258700	553600	705100	1258700	585500	(119600)	(673200)	(59800)	(336600)	(59800)	(336600)	11477200	(6667800)		
32	1500	16400	1258700	526100	732600	1258700	585500	(147100)	(673200)	(73550)	(336600)	(73550)	(336600)	11403650	(7004400)		
33	1500	16400	1258700	498900	759800	1258700	585500	(174300)	(673200)	(87150)	(336600)	(87150)	(336600)	11316500	(7341000)		
34	1500	16400	1258700	471400	787300	1258700	585500	(201800)	(673200)	(100900)	(336600)	(100900)	(336600)	11215600	(7677600)		
35	1500	16400	1258700	444200	814500	1258700	585500	(229000)	(673200)	(114500)	(336600)	(114500)	(336600)	11101100	(8014200)		
TOTAL	135000	1477000	93946500	38230600	55715900	93946500	51803500	(3912400)	(42143000)	(1956200)	(21071500)	11101100	(8014200)		AVG=		

Table B-122

PROCESS C, NONREGULATED FERTILIZER CO. ECONOMICS, 500 MW., NEW UNIT, 3.5% S IN COAL, 19-14-0 FERTILIZER PRODUCTION

FIXED INVESTMENT = $ 16356800
TOTAL INITIAL INVESTMENT = $ 17541800
OVERALL INTEREST RATE OF RETURN WITH PAYMENT = 0.4%
OVERALL INTEREST RATE OF RETURN WITHOUT PAYMENT = NEG

YEARS REQUIRED FOR PAYOUT WITH PAYMENT: 17.5
NO PAYOUT WITHOUT PAYMENT

YEARS AFTER POWER UNIT START	ANNUAL OPERATION KW-HR/KW	TONS/YEAR FERTILIZER	TOTAL FERTILIZER MFG. COST, $/YEAR	ALTERNATIVE WET-LIMESTONE PROCESS COST AS PAYMENT TO FERTILIZER COMPANY FOR AIR POLLUTION CONTROL, $/YEAR	NET FERTILIZER MFG COST, $/YEAR		NET FERTILIZER SALES REVENUE, $/YEAR	GROSS INCOME, $/YEAR		NET INCOME AFTER TAXES, $/YEAR		CASH FLOW, $/YEAR		CUMULATIVE CASH FLOW, $		ANNUAL RETURN ON INITIAL INVESTMENT, %	
					WITH PAYMENT	WITHOUT PAYMENT		WITH PAYMENT	WITHOUT PAYMENT	WITH PAYMENT	WITHOUT PAYMENT	WITH PAYMENT	WITHOUT PAYMENT	WITH PAYMENT	WITHOUT PAYMENT	WITH PAYMENT	WITHOUT PAYMENT
1	7000	134000	7081700	2150200	4931500	7081700	4596200	(335300)	(2485500)	(167650)	(1242750)	1468030	392930	1468030	392930		
2	7000	134000	7081700	2119600	4962100	7081700	4596200	(365900)	(2485500)	(182950)	(1242750)	1452730	392930	2920760	785860		
3	7000	134000	7081700	2089200	4992500	7081700	4596200	(396300)	(2485500)	(198150)	(1242750)	1437530	392930	4358290	1178790		
4	7000	134000	7081700	2058700	5023000	7081700	4596200	(426800)	(2485500)	(213400)	(1242750)	1422280	392930	5780570	1571720		
5	7000	134000	7081700	2028100	5053600	7081700	4596200	(457400)	(2485500)	(228700)	(1242750)	1406980	392930	7187550	1964650		
6	7000	134000	7081700	1997500	5084200	7081700	4596200	(488000)	(2485500)	(244000)	(1242750)	1391680	392930	8579230	2357580		
7	7000	134000	7081700	1967100	5114600	7081700	4596200	(518400)	(2485500)	(259200)	(1242750)	1376480	392930	9955710	2750510		
8	7000	134000	7081700	1936600	5145100	7081700	4596200	(548900)	(2485500)	(274450)	(1242750)	1361230	392930	11316940	3143440		
9	7000	134000	7081700	1906000	5175700	7081700	4596200	(579500)	(2485500)	(289750)	(1242750)	1345930	392930	12662870	3536370		
10	7000	134000	7081700	1875600	5206100	7081700	4596200	(609900)	(2485500)	(304950)	(1242750)	1330730	392930	13993600	3929300		
11	5000	95700	4173500	1640100	2533400	4173500	3314100	780700	(859400)	390350	(429700)	390350	(429700)	14383950	3499600	2.23	
12	5000	95700	4173500	1610000	2563500	4173500	3314100	750600	(859400)	375300	(429700)	375300	(429700)	14759250	3069900	2.14	
13	5000	95700	4173500	1579400	2594100	4173500	3314100	720000	(859400)	360000	(429700)	360000	(429700)	15119250	2640200	2.05	
14	5000	95700	4173500	1549000	2624500	4173500	3314100	689600	(859400)	344800	(429700)	344800	(429700)	15464050	2210500	1.97	
15	5000	95700	4173500	1518400	2655100	4173500	3314100	659000	(859400)	329500	(429700)	329500	(429700)	15793550	1780800	1.88	
16	3500	67000	3181200	1311600	1869600	3181200	2340300	470700	(840900)	235350	(420450)	235350	(420450)	16028900	1360350	1.34	
17	3500	67000	3181200	1281200	1900000	3181200	2340300	440300	(840900)	220150	(420450)	220150	(420450)	16249050	939900	1.26	
18	3500	67000	3181200	1250600	1930600	3181200	2340300	409700	(840900)	204850	(420450)	204850	(420450)	16453900	519450	1.17	
19	3500	67000	3181200	1220100	1961100	3181200	2340300	379200	(840900)	189600	(420450)	189600	(420450)	16643500	99000	1.08	
20	3500	67000	3181200	1189700	1991500	3181200	2340300	348800	(840900)	174400	(420450)	174400	(420450)	16817900	(321450)	0.99	
21	1500	28700	1758500	952200	806300	1758500	1017700	211400	(740800)	105700	(370400)	105700	(370400)	16923600	(691850)	0.60	
22	1500	28700	1758500	921600	836900	1758500	1017700	180800	(740800)	90400	(370400)	90400	(370400)	17014000	(1062250)	0.52	
23	1500	28700	1758500	891100	867400	1758500	1017700	150300	(740800)	75150	(370400)	75150	(370400)	17089150	(1432650)	0.43	
24	1500	28700	1758500	860700	897800	1758500	1017700	119900	(740800)	59950	(370400)	59950	(370400)	17149100	(1803050)	0.34	
25	1500	28700	1758500	830100	928400	1758500	1017700	89300	(740800)	44650	(370400)	44650	(370400)	17193750	(2173450)	0.25	
26	1500	28700	1758500	799500	959000	1758500	1017700	58700	(740800)	29350	(370400)	29350	(370400)	17223100	(2543850)	0.17	
27	1500	28700	1758500	769200	989300	1758500	1017700	28400	(740800)	14200	(370400)	14200	(370400)	17237300	(2914250)	0.08	
28	1500	28700	1758500	738400	1020100	1758500	1017700	(2400)	(740800)	(1200)	(370400)	(1200)	(370400)	17236100	(3284650)		
29	1500	28700	1758500	708100	1050400	1758500	1017700	(32700)	(740800)	(16350)	(370400)	(16350)	(370400)	17219750	(3655050)		
30	1500	28700	1758500	677400	1081100	1758500	1017700	(63400)	(740800)	(31700)	(370400)	(31700)	(370400)	17188050	(4025450)		
31	1500	28700	1758500	647100	1111400	1758500	1017700	(93700)	(740800)	(46850)	(370400)	(46850)	(370400)	17141200	(4395850)		
32	1500	28700	1758500	616500	1142000	1758500	1017700	(124300)	(740800)	(62150)	(370400)	(62150)	(370400)	17079050	(4766250)		
33	1500	28700	1758500	585900	1172600	1758500	1017700	(154900)	(740800)	(77450)	(370400)	(77450)	(370400)	17001600	(5136650)		
34	1500	28700	1758500	555600	1202900	1758500	1017700	(185200)	(740800)	(92600)	(370400)	(92600)	(370400)	16909000	(5507050)		
35	1500	28700	1758500	525000	1233500	1758500	1017700	(215800)	(740800)	(107900)	(370400)	(107900)	(370400)	16801100	(5877450)		
TOTAL	135000	2584000	133968000	45357100	88610900	133968000	89499500	888600	(44468500)	444300	(22234250)	16801100	(5877450)		AVG=	0.07	

Table B-123

PROCESS C, NONREGULATED FERTILIZER CO. ECONOMICS, 500 MW., EXISTING UNIT, 3.5% S IN COAL, 19-14-0 FERTILIZER PRODUCTION

FIXED INVESTMENT = $ 17329600
TOTAL INITIAL INVESTMENT = $ 18585600
OVERALL INTEREST RATE OF RETURN WITH PAYMENT = NEG
OVERALL INTEREST RATE OF RETURN WITHOUT PAYMENT = NEG

NO PAYOUT WITH PAYMENT
NO PAYOUT WITHOUT PAYMENT

YEARS AFTER POWER UNIT START	ANNUAL OPERATION KW-HR/KW	TONS/YEAR FERTILIZER	TOTAL FERTILIZER MFG. COST, $/YEAR	ALTERNATIVE WET-LIMESTONE PROCESS COST AS PAYMENT TO FERTILIZER COMPANY FOR AIR POLLUTION CONTROL, $/YEAR	NET FERTILIZER MFG COST, $/YEAR		NET FERTILIZER SALES REVENUE, $/YEAR	GROSS INCOME, $/YEAR		NET INCOME AFTER TAXES, $/YEAR		CASH FLOW, $/YEAR		CUMULATIVE CASH FLOW, $		ANNUAL RETURN ON INITIAL INVESTMENT, %	
					WITH PAYMENT	WITHOUT PAYMENT		WITH PAYMENT	WITHOUT PAYMENT	WITH PAYMENT	WITHOUT PAYMENT	WITH PAYMENT	WITHOUT PAYMENT	WITH PAYMENT	WITHOUT PAYMENT	WITH PAYMENT	WITHOUT PAYMENT
1																	
2																	
3																	
4	7000	137000	7563000	2261500	5301500	7563000	4695000	(606500)	(2868000)	(303250)	(1434000)	1429710	298960	1429710	298960		
5	7000	137000	7563000	2226100	5336900	7563000	4695000	(641900)	(2868000)	(320950)	(1434000)	1412010	298960	2841720	597920		
6	7000	137000	7563000	2191000	5372000	7563000	4695000	(677000)	(2868000)	(338500)	(1434000)	1394460	298960	4236180	896880		
7	7000	137000	7563000	2155600	5407400	7563000	4695000	(712400)	(2868000)	(356200)	(1434000)	1376760	298960	5612940	1195840		
8	7000	137000	7563000	2120500	5442500	7563000	4695000	(747500)	(2868000)	(373750)	(1434000)	1359210	298960	6972150	1494800		
9	7000	137000	7563000	2085100	5477900	7563000	4695000	(782900)	(2868000)	(391450)	(1434000)	1341510	298960	8313660	1793760		
10	7000	137000	7563000	2050000	5513000	7563000	4695000	(818000)	(2868000)	(409000)	(1434000)	1323960	298960	9637620	2092720		
11	5000	97900	6198100	1804000	4394100	6198100	3388300	(1005800)	(2809800)	(502900)	(1404900)	1230060	328060	10867680	2420780		
12	5000	97900	6198100	1768900	4429200	6198100	3388300	(1040900)	(2809800)	(520450)	(1404900)	1212510	328060	12080190	2748840		
13	5000	97900	6198100	1733500	4464600	6198100	3388300	(1076300)	(2809800)	(538150)	(1404900)	1194810	328060	13275000	3076900		
14	5000	97900	4465100	1698300	2766800	4465100	3388300	621500	(1076800)	310750	(538400)	310750	(538400)	13585750	2538500	1.67	
15	5000	97900	4465100	1663000	2802100	4465100	3388300	586200	(1076800)	293100	(538400)	293100	(538400)	13878850	2000100	1.58	
16	3500	68500	3400500	1447600	1952900	3400500	2391300	438400	(1009200)	219200	(504600)	219200	(504600)	14098050	1495500	1.18	
17	3500	68500	3400500	1412300	1988200	3400500	2391300	403100	(1009200)	201550	(504600)	201550	(504600)	14299600	990900	1.08	
18	3500	68500	3400500	1377100	2023400	3400500	2391300	367900	(1009200)	183950	(504600)	183950	(504600)	14483550	486300	0.99	
19	3500	68500	3400500	1341800	2058700	3400500	2391300	332600	(1009200)	166300	(504600)	166300	(504600)	14649850	(18300)	0.89	
20	3500	68500	3400500	1306600	2093900	3400500	2391300	297400	(1009200)	148700	(504600)	148700	(504600)	14798550	(522900)	0.80	
21	1500	29400	1876400	1061200	815200	1876400	1042200	227000	(834200)	113500	(417100)	113500	(417100)	14912050	(940000)	0.61	
22	1500	29400	1876400	1025900	850500	1876400	1042200	191700	(834200)	95850	(417100)	95850	(417100)	15007900	(1357100)	0.52	
23	1500	29400	1876400	990700	885700	1876400	1042200	156500	(834200)	78250	(417100)	78250	(417100)	15086150	(1774200)	0.42	
24	1500	29400	1876400	955400	921000	1876400	1042200	121200	(834200)	60600	(417100)	60600	(417100)	15146750	(2191300)	0.33	
25	1500	29400	1876400	920200	956200	1876400	1042200	86000	(834200)	43000	(417100)	43000	(417100)	15189750	(2608400)	0.23	
26	1500	29400	1876400	884900	991500	1876400	1042200	50700	(834200)	25350	(417100)	25350	(417100)	15215100	(3025500)	0.14	
27	1500	29400	1876400	849700	1026700	1876400	1042200	15500	(834200)	7750	(417100)	7750	(417100)	15222850	(3442600)	0.04	
28	1500	29400	1876400	814300	1062100	1876400	1042200	(19900)	(834200)	(9950)	(417100)	(9950)	(417100)	15212900	(3859700)		
29	1500	29400	1876400	779200	1097200	1876400	1042200	(55000)	(834200)	(27500)	(417100)	(27500)	(417100)	15185400	(4276800)		
30	1500	29400	1876400	743800	1132600	1876400	1042200	(90400)	(834200)	(45200)	(417100)	(45200)	(417100)	15140200	(4693900)		
31	1500	29400	1876400	708700	1167700	1876400	1042200	(125500)	(834200)	(62750)	(417100)	(62750)	(417100)	15077450	(5111000)		
32	1500	29400	1876400	673300	1203100	1876400	1042200	(160900)	(834200)	(80450)	(417100)	(80450)	(417100)	14997000	(5528100)		
33	1500	29400	1876400	638200	1238200	1876400	1042200	(196000)	(834200)	(98000)	(417100)	(98000)	(417100)	14899000	(5945200)		
34	1500	29400	1876400	602800	1273600	1876400	1042200	(231400)	(834200)	(115700)	(417100)	(115700)	(417100)	14783300	(6362300)		
35	1500	29400	1876400	567700	1308700	1876400	1042200	(266500)	(834200)	(133250)	(417100)	(133250)	(417100)	14650050	(6779400)		
TOTAL	114000	2232000	125614000	42856900	82755100	125614000	77396000	(5359100)	(48218000)	(2679550)	(24109000)	14650050	(6779400)		AVG=		

Table B-124

PROCESS C. NONREGULATED FERTILIZER CO. ECONOMICS, 500 MW., NEW UNIT, 5.0% S IN COAL, 19-14-0 FERTILIZER PRODUCTION

FIXED INVESTMENT = $ 17542900
TOTAL INITIAL INVESTMENT = $ 19057900
OVERALL INTEREST RATE OF RETURN WITH PAYMENT = 3.3%
OVERALL INTEREST RATE OF RETURN WITHOUT PAYMENT = NEG

YEARS REQUIRED FOR PAYOUT WITH PAYMENT: 11.0
NO PAYOUT WITHOUT PAYMENT

YEARS AFTER POWER UNIT START	ANNUAL OPERATION KW-HR/KW	TONS/YEAR FERTILIZER	TOTAL FERTILIZER MFG. COST, $/YEAR	ALTERNATIVE WET-LIMESTONE PROCESS COST AS PAYMENT TO FERTILIZER COMPANY FOR AIR POLLUTION CONTROL, $/YEAR	NET FERTILIZER MFG COST, $/YEAR WITH PAYMENT	NET FERTILIZER MFG COST, $/YEAR WITHOUT PAYMENT	NET FERTILIZER SALES REVENUE, $/YEAR	GROSS INCOME, $/YEAR WITH PAYMENT	GROSS INCOME, $/YEAR WITHOUT PAYMENT	NET INCOME AFTER TAXES, $/YEAR WITH PAYMENT	NET INCOME AFTER TAXES, $/YEAR WITHOUT PAYMENT	CASH FLOW, $/YEAR WITH PAYMENT	CASH FLOW, $/YEAR WITHOUT PAYMENT	CUMULATIVE CASH FLOW, $ WITH PAYMENT	CUMULATIVE CASH FLOW, $ WITHOUT PAYMENT	ANNUAL RETURN ON INITIAL INVESTMENT, % WITH PAYMENT	ANNUAL RETURN ON INITIAL INVESTMENT, % WITHOUT PAYMENT
1	7000	191400	8960900	2506500	6454400	8960900	6482700	28300	(2478200)	14150	(1239100)	1768440	515190	1768440	515190	0.07	
2	7000	191400	8960900	2473000	6487900	8960900	6482700	(5200)	(2478200)	(2600)	(1239100)	1751690	515190	3520130	1030380		
3	7000	191400	8960900	2439300	6521600	8960900	6482700	(38900)	(2478200)	(19450)	(1239100)	1734840	515190	5254970	1545570		
4	7000	191400	8960900	2405800	6555100	8960900	6482700	(72400)	(2478200)	(36200)	(1239100)	1718090	515190	6973060	2060760		
5	7000	191400	8960900	2372100	6588800	8960900	6482700	(106100)	(2478200)	(53050)	(1239100)	1701240	515190	8674300	2575950		
6	7000	191400	8960900	2338600	6622300	8960900	6482700	(139600)	(2478200)	(69800)	(1239100)	1684490	515190	10358790	3091140		
7	7000	191400	8960900	2304900	6656000	8960900	6482700	(173300)	(2478200)	(86650)	(1239100)	1667640	515190	12026430	3606330		
8	7000	191400	8960900	2271500	6689400	8960900	6482700	(206700)	(2478200)	(103350)	(1239100)	1650940	515190	13677370	4121520		
9	7000	191400	8960900	2238000	6722900	8960900	6482700	(240200)	(2478200)	(120100)	(1239100)	1634190	515190	15311560	4636710		
10	7000	191400	8960900	2204300	6756600	8960900	6482700	(273900)	(2478200)	(136950)	(1239100)	1617340	515190	16928900	5151900		
11	5000	136700	5351700	1903900	3447800	5351700	4684700	1236900	(667000)	618450	(333500)	618450	(333500)	17547350	4818400	3.25	
12	5000	136700	5351700	1870200	3481500	5351700	4684700	1203200	(667000)	601600	(333500)	601600	(333500)	18148950	4484900	3.16	
13	5000	136700	5351700	1836700	3515000	5351700	4684700	1169700	(667000)	584850	(333500)	584850	(333500)	18733800	4151400	3.07	
14	5000	136700	5351700	1803000	3548700	5351700	4684700	1136000	(667000)	568000	(333500)	568000	(333500)	19301800	3817900	2.99	
15	5000	136700	5351700	1769500	3582200	5351700	4684700	1102500	(667000)	551250	(333500)	551250	(333500)	19853050	3484400	2.89	
16	3500	95700	4049500	1512100	2537400	4049500	3314100	776700	(735400)	388350	(367700)	388350	(367700)	20241400	3116700	2.04	
17	3500	95700	4049500	1478400	2571100	4049500	3314100	743000	(735400)	371500	(367700)	371500	(367700)	20612900	2749000	1.95	
18	3500	95700	4049500	1444900	2604600	4049500	3314100	709500	(735400)	354750	(367700)	354750	(367700)	20967650	2381300	1.86	
19	3500	95700	4049500	1411300	2638200	4049500	3314100	675900	(735400)	337950	(367700)	337950	(367700)	21305600	2013600	1.77	
20	3500	95700	4049500	1377800	2671700	4049500	3314100	642400	(735400)	321200	(367700)	321200	(367700)	21626800	1645900	1.69	
21	1500	41000	2198000	1078200	1119800	2198000	1446100	326300	(751900)	163150	(375950)	163150	(375950)	21789950	1269950	0.86	
22	1500	41000	2198000	1044700	1153300	2198000	1446100	292800	(751900)	146400	(375950)	146400	(375950)	21936350	894000	0.77	
23	1500	41000	2198000	1011900	1186100	2198000	1446100	260000	(751900)	130000	(375950)	130000	(375950)	22066350	518050	0.68	
24	1500	41000	2198000	977500	1220500	2198000	1446100	225600	(751900)	112800	(375950)	112800	(375950)	22179150	142100	0.59	
25	1500	41000	2198000	944000	1254000	2198000	1446100	192100	(751900)	96050	(375950)	96050	(375950)	22275200	(233850)	0.50	
26	1500	41000	2198000	910300	1287700	2198000	1446100	158400	(751900)	79200	(375950)	79200	(375950)	22354400	(609800)	0.42	
27	1500	41000	2198000	876800	1321200	2198000	1446100	124900	(751900)	62450	(375950)	62450	(375950)	22416850	(985750)	0.33	
28	1500	41000	2198000	843100	1354900	2198000	1446100	91200	(751900)	45600	(375950)	45600	(375950)	22462450	(1361700)	0.24	
29	1500	41000	2198000	809600	1388400	2198000	1446100	57700	(751900)	28850	(375950)	28850	(375950)	22491300	(1737650)	0.15	
30	1500	41000	2198000	776200	1421800	2198000	1446100	24300	(751900)	12150	(375950)	12150	(375950)	22503450	(2113600)	0.06	
31	1500	41000	2198000	742500	1455500	2198000	1446100	(9400)	(751900)	(4700)	(375950)	(4700)	(375950)	22498750	(2489550)		
32	1500	41000	2198000	708800	1489200	2198000	1446100	(43100)	(751900)	(21550)	(375950)	(21550)	(375950)	22477200	(2865500)		
33	1500	41000	2198000	675300	1522700	2198000	1446100	(76600)	(751900)	(38300)	(375950)	(38300)	(375950)	22438900	(3241450)		
34	1500	41000	2198000	641800	1556200	2198000	1446100	(110100)	(751900)	(55050)	(375950)	(55050)	(375950)	22383850	(3617400)		
35	1500	41000	2198000	608100	1589900	2198000	1446100	(143800)	(751900)	(71900)	(375950)	(71900)	(375950)	22311950	(3993350)		
TOTAL	135000	3691000	169585000	52610600	116974400	169585000	126512500	9538100	(43072500)	4769050	(21536250)	22311950	(3993350)		AVG=	0.71	

Table B-125

PROCESS C. NONREGULATED FERTILIZER CO. ECONOMICS. 1000 MW., NEW UNIT, 3.5% S IN COAL, 19-14-0 FERTILIZER PRODUCTION

FIXED INVESTMENT = $ 24639300
TOTAL INITIAL INVESTMENT = $ 26649300
OVERALL INTEREST RATE OF RETURN WITH PAYMENT = 4.0%
OVERALL INTEREST RATE OF RETURN WITHOUT PAYMENT = NEG

YEARS REQUIRED FOR PAYOUT WITH PAYMENT: 10.0
NO PAYOUT WITHOUT PAYMENT

YEARS AFTER POWER UNIT START	ANNUAL OPERATION KW-HR/KW	TONS/YEAR FERTILIZER	TOTAL FERTILIZER MFG. COST, $/YEAR	ALTERNATIVE WET-LIMESTONE PROCESS COST AS PAYMENT TO FERTILIZER COMPANY FOR AIR POLLUTION CONTROL, $/YEAR	NET FERTILIZER MFG COST, $/YEAR WITH PAYMENT	NET FERTILIZER MFG COST, $/YEAR WITHOUT PAYMENT	NET FERTILIZER SALES REVENUE, $/YEAR	GROSS INCOME, $/YEAR WITH PAYMENT	GROSS INCOME, $/YEAR WITHOUT PAYMENT	NET INCOME AFTER TAXES, $/YEAR WITH PAYMENT	NET INCOME AFTER TAXES, $/YEAR WITHOUT PAYMENT	CASH FLOW, $/YEAR WITH PAYMENT	CASH FLOW, $/YEAR WITHOUT PAYMENT	CUMULATIVE CASH FLOW, $ WITH PAYMENT	CUMULATIVE CASH FLOW, $ WITHOUT PAYMENT	ANNUAL RETURN ON INITIAL INVESTMENT, % WITH PAYMENT	ANNUAL RETURN ON INITIAL INVESTMENT, % WITHOUT PAYMENT
1	7000	259500	1181430	3362400	8451900	11814300	8677700	225900	(3136600)	112900	(1568300)	2576830	895630	2576830	895630	0.42	
2	7000	259500	11814300	3317000	8497300	11814300	8677700	180400	(3136600)	90200	(1568300)	2554130	895630	5130960	1791260	0.34	
3	7000	259500	11814300	3271900	8542400	11814300	8677700	135300	(3136600)	67650	(1568300)	2531580	895630	7662540	2686890	0.25	
4	7000	259500	11814300	3226500	8587800	11814300	8677700	89900	(3136600)	44950	(1568300)	2508880	895630	10171420	3582520	0.17	
5	7000	259500	11814300	3181200	8633100	11814300	8677700	44600	(3136600)	22300	(1568300)	2486230	895630	12657650	4478150	0.08	
6	7000	259500	11814300	3135800	8678500	11814300	8677700	(800)	(3136600)	(400)	(1568300)	2463530	895630	15121180	5373780		
7	7000	259500	11814300	3090700	8723600	11814300	8677700	(45900)	(3136600)	(22950)	(1568300)	2440980	895630	17562160	6269410		
8	7000	259500	11814300	3045400	8768900	11814300	8677700	(91200)	(3136600)	(45600)	(1568300)	2418330	895630	19980490	7165040		
9	7000	259500	11814300	3000000	8814300	11814300	8677700	(136600)	(3136600)	(68300)	(1568300)	2395630	895630	22376120	8060670		
10	7000	259500	11814300	2954900	8859400	11814300	8677700	(181700)	(3136600)	(90850)	(1568300)	2373080	895630	24749200	8956300		
11	5000	185400	7098900	2565100	4533800	7098900	6286900	1753100	(812000)	876550	(406000)	876550	(406000)	25625750	8550300	3.29	
12	5000	185400	7098900	2519800	4579100	7098900	6286900	1707800	(812000)	853900	(406000)	853900	(406000)	26479650	8144300	3.20	
13	5000	185400	7098900	2474500	4624400	7098900	6286900	1662500	(812000)	831250	(406000)	831250	(406000)	27310900	7738300	3.12	
14	5000	185400	7098900	2429300	4669600	7098900	6286900	1617300	(812000)	808650	(406000)	808650	(406000)	28119550	7332300	3.03	
15	5000	185400	7098900	2384000	4714900	7098900	6286900	1572000	(812000)	786000	(406000)	786000	(406000)	28905550	6926300	2.95	
16	3500	129800	5353300	2053500	3299800	5353300	4456000	1156200	(897300)	578100	(448650)	578100	(448650)	29483650	6477650	2.17	
17	3500	129800	5353300	2008400	3344900	5353300	4456000	1111100	(897300)	555550	(448650)	555550	(448650)	30039200	6029000	2.08	
18	3500	129800	5353300	1963100	3390200	5353300	4456000	1065800	(897300)	532900	(448650)	532900	(448650)	30572100	5580350	2.00	
19	3500	129800	5353300	1917700	3435600	5353300	4456000	1020400	(897300)	510200	(448650)	510200	(448650)	31082300	5131700	1.91	
20	3500	129800	5353300	1872400	3480900	5353300	4456000	975100	(897300)	487550	(448650)	487550	(448650)	31569850	4683050	1.83	
21	1500	55600	2880500	1496500	1384000	2880500	1949300	565300	(931200)	282650	(465600)	282650	(465600)	31852500	4217450	1.06	
22	1500	55600	2880500	1451200	1429300	2880500	1949300	520000	(931200)	260000	(465600)	260000	(465600)	32112500	3751850	0.98	
23	1500	55600	2880500	1405800	1474700	2880500	1949300	474600	(931200)	237300	(465600)	237300	(465600)	32349800	3286250	0.89	
24	1500	55600	2880500	1360700	1519800	2880500	1949300	429500	(931200)	214750	(465600)	214750	(465600)	32564550	2820650	0.81	
25	1500	55600	2880500	1315400	1565100	2880500	1949300	384200	(931200)	192100	(465600)	192100	(465600)	32756650	2355050	0.72	
26	1500	55600	2880500	1270000	1610500	2880500	1949300	338800	(931200)	169400	(465600)	169400	(465600)	32926050	1889450	0.64	
27	1500	55600	2880500	1224700	1655800	2880500	1949300	293500	(931200)	146750	(465600)	146750	(465600)	33072800	1423850	0.55	
28	1500	55600	2880500	1179500	1701000	2880500	1949300	248300	(931200)	124150	(465600)	124150	(465600)	33196950	958250	0.47	
29	1500	55600	2880500	1134200	1746300	2880500	1949300	203000	(931200)	101500	(465600)	101500	(465600)	33298450	492650	0.38	
30	1500	55600	2880500	1088800	1791700	2880500	1949300	157600	(931200)	78800	(465600)	78800	(465600)	33377250	27050	0.30	
31	1500	55600	2880500	1043700	1836800	2880500	1949300	112500	(931200)	56250	(465600)	56250	(465600)	33433500	(438550)	0.21	
32	1500	55600	2880500	998400	1882100	2880500	1949300	67200	(931200)	33600	(465600)	33600	(465600)	33467100	(904150)	0.13	
33	1500	55600	2880500	953000	1927500	2880500	1949300	21800	(931200)	10900	(465600)	10900	(465600)	33478000	(1369750)	0.04	
34	1500	55600	2880500	907700	1972800	2880500	1949300	(23500)	(931200)	(11750)	(465600)	(11750)	(465600)	33466250	(1835350)		
35	1500	55600	2880500	862500	2018000	2880500	1949300	(68700)	(931200)	(34350)	(465600)	(34350)	(465600)	33431900	(2300950)		
TOTAL	135000	5005000	223611500	71465700	152145800	223611500	169731000	17585200	(53680500)	8792600	(26940250)	33431900	(2300950)		AVG=	0.94	

Table B-126

PROCESS C, NONREGULATED FERTILIZER CO. ECONOMICS, 1000 MW., EXISTING UNIT, 3.5% S IN COAL, 19-14-0 FERTILIZER PRODUCTION

FIXED INVESTMENT = $ 26646400
TOTAL INITIAL INVESTMENT = $ 28821400
OVERALL INTEREST RATE OF RETURN WITH PAYMENT = 2.5%
OVERALL INTEREST RATE OF RETURN WITHOUT PAYMENT = NEG

YEARS REQUIRED FOR PAYOUT WITH PAYMENT: 11.8
NO PAYOUT WITHOUT PAYMENT

YEARS AFTER POWER UNIT START	ANNUAL OPERATION KW-HR/KW	TONS/YEAR FERTILIZER	TOTAL FERTILIZER MFG. COST, $/YEAR	ALTERNATIVE WET-LIMESTONE PROCESS COST AS PAYMENT TO FERTILIZER COMPANY FOR AIR POLLUTION CONTROL, $/YEAR	NET FERTILIZER MFG COST, $/YEAR		NET FERTILIZER SALES REVENUE, $/YEAR	GROSS INCOME, $/YEAR		NET INCOME AFTER TAXES, $/YEAR		CASH FLOW, $/YEAR		CUMULATIVE CASH FLOW, $		ANNUAL RETURN ON INITIAL INVESTMENT, %	
					WITH PAYMENT	WITHOUT PAYMENT		WITH PAYMENT	WITHOUT PAYMENT	WITH PAYMENT	WITHOUT PAYMENT	WITH PAYMENT	WITHOUT PAYMENT	WITH PAYMENT	WITHOUT PAYMENT	WITH PAYMENT	WITHOUT PAYMENT
1																	
2																	
3																	
4	7000	268000	12462900	3587300	8875600	12462900	8951200	75600	(3511700)	37800	(1755850)	2702440	908790	2702440	908790	0.13	
5	7000	268000	12462900	3533800	8929100	12462900	8951200	22100	(3511700)	11050	(1755850)	2675690	908790	5378130	1817580	0.04	
6	7000	268000	12462900	3480600	8982300	12462900	8951200	(31100)	(3511700)	(15550)	(1755850)	2649090	908790	8027220	2726370		
7	7000	268000	12462900	3427200	9035700	12462900	8951200	(84500)	(3511700)	(42250)	(1755850)	2622390	908790	10649610	3635160		
8	7000	268000	12462900	3373900	9089000	12462900	8951200	(137800)	(3511700)	(68900)	(1755850)	2595740	908790	13245350	4543950		
9	7000	268000	12462900	3319900	9143000	12462900	8951200	(191800)	(3511700)	(95900)	(1755850)	2568740	908790	15814090	5452740		
10	7000	268000	12462900	3267200	9195700	12462900	8951200	(244500)	(3511700)	(122250)	(1755850)	2542390	908790	18356480	6361530		
11	5000	191400	10111400	2857000	7254400	10111400	6482700	(771700)	(3628700)	(385850)	(1814350)	2278790	850290	20635270	7211820		
12	5000	191400	10111400	2803800	7307600	10111400	6482700	(824900)	(3628700)	(412450)	(1814350)	2252190	850290	22887460	8062110		
13	5000	191400	10111400	2750300	7361100	10111400	6482700	(878400)	(3628700)	(439200)	(1814350)	2225440	850290	25112900	8912400		
14	5000	191400	7446700	2696900	4749800	7446700	6482700	1732900	(964000)	866450	(482000)	866450	(482000)	25979350	8430400	3.01	
15	5000	191400	7446700	2643600	4803100	7446700	6482700	1679600	(964000)	839800	(482000)	839800	(482000)	26819150	7948400	2.91	
16	3500	134000	5622300	2294300	3328000	5622300	4596200	1268200	(1026100)	634100	(513050)	634100	(513050)	27453250	7435350	2.20	
17	3500	134000	5622300	2241100	3381200	5622300	4596200	1215000	(1026100)	607500	(513050)	607500	(513050)	28060750	6922300	2.11	
18	3500	134000	5622300	2187600	3434700	5622300	4596200	1161500	(1026100)	580750	(513050)	580750	(513050)	28641500	6409250	2.01	
19	3500	134000	5622300	2134400	3487900	5622300	4596200	1108300	(1026100)	554150	(513050)	554150	(513050)	29195650	5896200	1.92	
20	3500	134000	5622300	2080900	3541400	5622300	4596200	1054800	(1026100)	527400	(513050)	527400	(513050)	29723050	5383150	1.83	
21	1500	57400	3036200	1685300	1350900	3036200	2011300	660400	(1024900)	330200	(512450)	330200	(512450)	30053250	4870700	1.15	
22	1500	57400	3036200	1632000	1404200	3036200	2011300	607100	(1024900)	303550	(512450)	303550	(512450)	30356800	4358250	1.05	
23	1500	57400	3036200	1578600	1457600	3036200	2011300	553700	(1024900)	276850	(512450)	276850	(512450)	30633650	3845800	0.96	
24	1500	57400	3036200	1525300	1510900	3036200	2011300	500400	(1024900)	250200	(512450)	250200	(512450)	30883850	3333350	0.87	
25	1500	57400	3036200	1471900	1564300	3036200	2011300	447000	(1024900)	223500	(512450)	223500	(512450)	31107350	2820900	0.78	
26	1500	57400	3036200	1418600	1617600	3036200	2011300	393700	(1024900)	196850	(512450)	196850	(512450)	31304200	2308450	0.68	
27	1500	57400	3036200	1365200	1671000	3036200	2011300	340300	(1024900)	170150	(512450)	170150	(512450)	31474350	1796000	0.59	
28	1500	57400	3036200	1311900	1724300	3036200	2011300	287000	(1024900)	143500	(512450)	143500	(512450)	31617850	1283550	0.50	
29	1500	57400	3036200	1258500	1777700	3036200	2011300	233600	(1024900)	116800	(512450)	116800	(512450)	31734650	771100	0.41	
30	1500	57400	3036200	1205000	1831200	3036200	2011300	180100	(1024900)	90050	(512450)	90050	(512450)	31824700	258650	0.31	
31	1500	57400	3036200	1151800	1884400	3036200	2011300	126900	(1024900)	63450	(512450)	63450	(512450)	31888150	(253800)	0.22	
32	1500	57400	3036200	1098300	1937900	3036200	2011300	73400	(1024900)	36700	(512450)	36700	(512450)	31924850	(766250)	0.13	
33	1500	57400	3036200	1045100	1991100	3036200	2011300	20200	(1024900)	10100	(512450)	10100	(512450)	31934950	(1278700)	0.04	
34	1500	57400	3036200	991600	2044600	3036200	2011300	(33300)	(1024900)	(16650)	(512450)	(16650)	(512450)	31918300	(1791150)		
35	1500	57400	3036200	938400	2097800	3036200	2011300	(86500)	(1024900)	(43250)	(512450)	(43250)	(512450)	31875050	(2303600)		
TOTAL	114000	4364000	206122400	68357300	137765100	206122400	148222400	10457300	(57900000)	5228650	(28950000)	31875050	(2303600)		AVG=	0.57	

Table B-127

PROCESS A, COOPERATIVE ECONOMICS, 200 MW., EXISTING UNIT, 3.5% S IN COAL, 28-14-0 FERTILIZER PRODUCTION

FIXED INVESTMENT = $ 9640000
TOTAL INITIAL INVESTMENT = $ 10441000
OVERALL INTEREST RATE OF RETURN WITH DEDUCT = NEG
OVERALL INTEREST RATE OF RETURN WITHOUT DEDUCT = NEG

NO PAYOUT WITH DEDUCT
NO PAYOUT WITHOUT DEDUCT

YEARS AFTER POWER UNIT START	ANNUAL OPERATION KW-HR/KW	TONS/YEAR FERTILIZER	TOTAL NH3 SCRUBBING OPERATING COST INCL REGUL. ROI FOR POWER CO., $/YEAR	ALTERNATE WET-LIMESTONE PROCESS AIR POLLUTION CONTROL COST, $/YEAR	NET NH3 SCRUBBING COST IF DEDUCTION TAKEN FOR WET-LIMESTONE PROCESS COST, $/YEAR	NET FERTILIZER MFG COST USING (NH4)2SO4 FROM POWER PLANT, $/YEAR WITH DEDUCT	NET FERTILIZER MFG COST USING (NH4)2SO4 FROM POWER PLANT, $/YEAR WITHOUT DEDUCT	NET FERTILIZER SALES REVENUE, $/YEAR	GROSS INCOME, $/YEAR WITH DEDUCT	GROSS INCOME, $/YEAR WITHOUT DEDUCT	NET INCOME AFTER TAXES, $/YEAR WITH DEDUCT	NET INCOME AFTER TAXES, $/YEAR WITHOUT DEDUCT	CASH FLOW, $/YEAR WITH DEDUCT	CASH FLOW, $/YEAR WITHOUT DEDUCT	CUMULATIVE CASH FLOW, $ WITH DEDUCT	CUMULATIVE CASH FLOW, $ WITHOUT DEDUCT	ANNUAL RETURN ON INITIAL INVESTMENT, % WITH DEDUCT	ANNUAL RETURN ON INITIAL INVESTMENT, % WITHOUT DEDUCT
1																		
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9	7000	128600	1781500	1087900	693600	5401800	6489700	5460400	58600	(1029300)	29300	(514650)	993300	449350	993300	449350	0.29	
10	7000	128600	1759300	1067700	691600	5399800	6467500	5460400	60600	(1007100)	30300	(503550)	994300	460450	1987600	909800	0.29	
11	5000	91700	1464900	947100	517800	4332700	5279800	3930300	(402400)	(1349500)	(201200)	(674750)	762800	289250	2750400	1199050		
12	5000	91700	1442700	927000	515700	4330600	5257600	3930300	(400300)	(1327300)	(200150)	(663650)	763850	300350	3514250	1499400		
13	5000	91700	1420400	906800	513600	4328500	5235300	3930300	(398200)	(1305000)	(199100)	(652500)	764900	311500	4279150	1810900		
14	5000	91700	1398400	886600	511800	4326700	5213300	3930300	(396400)	(1283000)	(198200)	(641500)	765900	322500	5044950	2133400		
15	5000	91700	1376100	866400	509700	4324600	5191000	3930300	(394300)	(1260700)	(197150)	(630350)	766850	333650	5811900	2467050		
16	3500	64200	1143400	762900	380500	3499800	4262700	2774100	(725700)	(1488600)	(362850)	(744300)	601150	219700	6412950	2686750		
17	3500	64200	1121300	742800	378500	3497800	4240600	2774100	(723700)	(1466500)	(361850)	(733250)	602150	230750	7015100	2917500		
18	3500	64200	1099100	722600	376500	3495800	4218400	2774100	(721700)	(1444300)	(360850)	(722150)	603150	241850	7618250	3159350		
19	3500	64200	1076800	702400	374400	2529700	3232100	2774100	244400	(458000)	122200	(229000)	122200	(229000)	7740450	2930350	1.17	
20	3500	64200	1054900	682200	372600	2527900	3210100	2774100	246200	(436000)	123100	(218000)	123100	(218000)	7863550	2712350	1.17	
21	1500	27600	738900	553000	195900	1354500	1907500	1209400	(145100)	(698100)	(72550)	(349050)	(72550)	(349050)	7791000	2363300		
22	1500	27600	716600	532800	183800	1352400	1885200	1209400	(143000)	(675800)	(71500)	(337900)	(71500)	(337900)	7719500	2025400		
23	1500	27600	694600	512600	182000	1350600	1863200	1209400	(141200)	(653800)	(70600)	(326900)	(70600)	(326900)	7648900	1698500		
24	1500	27600	672300	492400	179900	1348500	1840900	1209400	(139100)	(631500)	(69550)	(315750)	(69550)	(315750)	7579350	1382750		
25	1500	27600	650100	472300	177800	1346400	1818700	1209400	(137000)	(609300)	(68500)	(304650)	(68500)	(304650)	7510850	1078100		
26	1500	27600	628000	452100	175900	1344500	1796500	1209400	(135100)	(587200)	(67550)	(293600)	(67550)	(293600)	7443300	784500		
27	1500	27600	605800	431900	173900	1342500	1774400	1209400	(133100)	(565000)	(66550)	(282500)	(66550)	(282500)	7376750	502000		
28	1500	27600	583500	411700	171800	1340400	1752100	1209400	(131000)	(542700)	(65500)	(271350)	(65500)	(271350)	7311250	230650		
29	1500	27600	561500	391600	169900	1338500	1730100	1209400	(129100)	(520700)	(64550)	(260350)	(64550)	(260350)	7246700	(29700)		
30	1500	27600	539200	371400	167800	1336400	1707800	1209400	(127000)	(498400)	(63500)	(249200)	(63500)	(249200)	7183200	(278900)		
31	1500	27600	517000	351200	165800	1334400	1685600	1209400	(125000)	(476200)	(62500)	(238100)	(62500)	(238100)	7120700	(517000)		
32	1500	27600	494900	331000	163900	1332500	1663500	1209400	(123100)	(454100)	(61550)	(227050)	(61550)	(227050)	7059150	(744050)		
33	1500	27600	472700	310900	161800	1330400	1641300	1209400	(121000)	(431900)	(60500)	(215950)	(60500)	(215950)	6999650	(960000)		
34	1500	27600	450400	290700	159700	1328300	1619000	1209400	(118900)	(409600)	(59450)	(204800)	(59450)	(204800)	6939200	(1164800)		
35	1500	27600	428400	270500	157900	1326500	1597000	1209400	(117100)	(387600)	(58550)	(193800)	(58550)	(193800)	6880650	(1358600)		
TOTAL	79000	1450700	24892600	16478500	8414100	68102500	84581000	62583800	(5518700)	(21997200)	(2759350)	(10998600)	6880650	(1358600)		AVG=		

Table B-128

PROCESS A, COOPERATIVE ECONOMICS, 500 MW., NEW UNIT, 2.0% S IN COAL, 28-14-0 FERTILIZER PRODUCTION

FIXED INVESTMENT = $ 11210000
TOTAL INITIAL INVESTMENT = $ 12326400
OVERALL INTEREST RATE OF RETURN WITH DEDUCT = 7.3%
OVERALL INTEREST RATE OF RETURN WITHOUT DEDUCT = NEG

YEARS REQUIRED FOR PAYOUT WITH DEDUCT: 8.0
NO PAYOUT WITHOUT DEDUCT

YEARS AFTER POWER UNIT START	ANNUAL OPERATION KW-HR/KW	TONS/YEAR FERTILIZER	TOTAL NH3 SCRUBBING OPERATING COST INCL REGUL.ROI FOR POWER CO.,$/YEAR	ALTERNATE WET-LIMESTONE PROCESS AIR POLLUTION CONTROL COST, $/YEAR	NET NH3 SCRUBBING COST IF DEDUCTION TAKEN FOR WET-LIMESTONE PROCESS COST, $/YEAR	NET FERTILIZER MFG COST USING (NH4)2SO4 FROM POWER PLANT, $/YEAR WITH DEDUCT	NET FERTILIZER MFG COST USING (NH4)2SO4 FROM POWER PLANT, $/YEAR WITHOUT DEDUCT	NET FERTILIZER SALES REVENUE, $/YEAR	GROSS INCOME, $/YEAR WITH DEDUCT	GROSS INCOME, $/YEAR WITHOUT DEDUCT	NET INCOME AFTER TAXES, $/YEAR WITH DEDUCT	NET INCOME AFTER TAXES, $/YEAR WITHOUT DEDUCT	CASH FLOW, $/YEAR WITH DEDUCT	CASH FLOW, $/YEAR WITHOUT DEDUCT	CUMULATIVE CASH FLOW, $ WITH DEDUCT	CUMULATIVE CASH FLOW, $ WITHOUT DEDUCT	ANNUAL RETURN ON INITIAL INVESTMENT, % WITH DEDUCT	ANNUAL RETURN ON INITIAL INVESTMENT, % WITHOUT DEDUCT
1	7000	173600	2892800	1800000	1092800	6744200	8544200	7301600	557400	(1242600)	278700	(621300)	1399700	499700	1399700	499700	2.26	
2	7000	173600	2860100	1772800	1087300	6738700	8511500	7301600	562900	(1209900)	281450	(604950)	1402450	516050	2802150	1015750	2.28	
3	7000	173600	2827800	1749100	1078700	6730100	8479200	7301600	571500	(1177600)	285750	(588800)	1406750	532200	4208900	1547950	2.32	
4	7000	173600	2795100	1719800	1076300	6727700	8446500	7301600	573900	(1144900)	286950	(572450)	1407950	548550	5616850	2096500	2.33	
5	7000	173600	2762500	1690600	1071900	6723300	8413900	7301600	578300	(1112300)	289150	(556150)	1410150	564850	7027000	2661350	2.35	
6	7000	173600	2729800	1663400	1066400	6717800	8381200	7301600	583800	(1079600)	291900	(539800)	1412900	581200	8439900	3242550	2.37	
7	7000	173600	2697400	1635900	1061500	6712900	8348800	7301600	588700	(1047200)	294350	(523600)	1415350	597400	9855250	3839950	2.39	
8	7000	173600	2664700	1608700	1056000	6707400	8316100	7301600	594200	(1014500)	297100	(507250)	1418100	613750	11273350	4453700	2.41	
9	7000	173600	2632000	1581200	1050800	6702200	8283400	7301600	599400	(981800)	299700	(490900)	1420700	630100	12694050	5083800	2.43	
10	7000	173600	2599600	1553800	1045800	6697200	8251000	7301600	604400	(949400)	302200	(474700)	1423200	646300	14117250	5730100	2.45	
11	5000	123900	2174700	1379800	794900	4230700	5610500	5268200	1037500	(342300)	518750	(171150)	518750	(171150)	14636000	5558950	4.21	
12	5000	123900	2142100	1352300	789800	4225600	5577900	5268200	1042600	(309700)	521300	(154850)	521300	(154850)	15157300	5404100	4.23	
13	5000	123900	2109400	1325100	784300	4220100	5545200	5268200	1048100	(277000)	524050	(138500)	524050	(138500)	15681350	5265600	4.25	
14	5000	123900	2077000	1297900	779100	4214900	5512800	5268200	1053300	(244600)	526650	(122300)	526650	(122300)	16208000	5143300	4.27	
15	5000	123900	2044300	1270400	773900	4209700	5480100	5268200	1058500	(211900)	529250	(105950)	529250	(105950)	16737250	5037350	4.29	
16	3500	86700	1707700	1114100	593600	3179600	4293700	3721200	541600	(572500)	270800	(286250)	270800	(286250)	17008050	4751100	2.20	
17	3500	86700	1675200	1086700	588500	3174500	4261200	3721200	546700	(540000)	273350	(270000)	273350	(270000)	17281400	4481100	2.22	
18	3500	86700	1642600	1059200	583400	3169400	4228600	3721200	551800	(507400)	275900	(253700)	275900	(253700)	17557300	4227400	2.24	
19	3500	86700	1609900	1032000	577900	3163900	4195900	3721200	557300	(474700)	278650	(237350)	278650	(237350)	17835950	3990050	2.26	
20	3500	86700	1577500	1004500	573000	3159000	4163500	3721200	562200	(442300)	281100	(221150)	281100	(221150)	18117050	3768900	2.28	
21	1500	37200	1117600	827100	290500	1675800	2502900	1623000	(52800)	(879900)	(26400)	(439950)	(26400)	(439950)	18090650	3328950		
22	1500	37200	1085000	799800	285200	1670500	2470300	1623000	(47500)	(847300)	(23750)	(423650)	(23750)	(423650)	18066900	2905300		
23	1500	37200	1052300	772400	279900	1665200	2437600	1623000	(42200)	(814600)	(21100)	(407300)	(21100)	(407300)	18045800	2498000		
24	1500	37200	1019900	745100	274900	1660100	2405200	1623000	(37100)	(782200)	(18550)	(391100)	(18550)	(391100)	18027250	2106900		
25	1500	37200	987200	717700	269500	1654800	2372500	1623000	(31800)	(749500)	(15900)	(374750)	(15900)	(374750)	18011350	1732150		
26	1500	37200	954500	690400	264100	1649400	2339800	1623000	(26400)	(716800)	(13200)	(358400)	(13200)	(358400)	17998150	1373750		
27	1500	37200	922100	663000	259100	1644400	2307400	1623000	(21400)	(684400)	(10700)	(342200)	(10700)	(342200)	17987450	1031550		
28	1500	37200	889400	635500	253900	1639200	2274700	1623000	(16200)	(651700)	(8100)	(325850)	(8100)	(325850)	17979350	705700		
29	1500	37200	856800	608300	248500	1633800	2242100	1623000	(10800)	(619100)	(5400)	(309550)	(5400)	(309550)	17973950	396150		
30	1500	37200	824100	580800	243300	1628600	2209400	1623000	(5600)	(586400)	(2800)	(293200)	(2800)	(293200)	17971150	102950		
31	1500	37200	791700	553600	238100	1623400	2177000	1623000	(400)	(554000)	(200)	(277000)	(200)	(277000)	17970950	(174050)		
32	1500	37200	759000	526100	232900	1618200	2144300	1623000	4800	(521300)	2400	(260650)	2400	(260650)	17973350	(434700)	0.02	
33	1500	37200	726400	498900	227500	1612800	2111700	1623000	10200	(488700)	5100	(244350)	5100	(244350)	17978450	(679050)	0.04	
34	1500	37200	693900	471400	222500	1607800	2079200	1623000	15200	(456200)	7600	(228100)	7600	(228100)	17986050	(907150)	0.06	
35	1500	37200	661300	444200	217100	1602400	2046600	1623000	20600	(423600)	10300	(211800)	10300	(211800)	17996350	(1118950)	0.08	
TOTAL	135000	3347000	59563400	38230600	21332800	129735300	166965900	142308000	13572700	(24657900)	6786350	(12328950)	17996350	(1118950)		AVG=	1.57	

Table B-129

PROCESS A, COOPERATIVE ECONOMICS, 500 MW., NEW UNIT, 3.5% S IN COAL, 28-14-0 FERTILIZER PRODUCTION

FIXED INVESTMENT = $ 15580000
TOTAL INITIAL INVESTMENT = $ 17435500
OVERALL INTEREST RATE OF RETURN WITH DEDUCT = 13.2%
OVERALL INTEREST RATE OF RETURN WITHOUT DEDUCT = NEG

YEARS REQUIRED FOR PAYOUT WITH DEDUCT: 6.1
YEARS REQUIRED FOR PAYOUT WITHOUT DEDUCT: 10.0

YEARS AFTER POWER UNIT START	ANNUAL OPERATION KW-HR/KW	TONS/YEAR FERTILIZER	TOTAL NH3 SCRUBBING OPERATING COST INCL REGUL.ROI FOR POWER CO.,$/YEAR	ALTERNATE WET-LIME-STONE PROCESS AIR POLLUTION CONTROL COST, $/YEAR	NET NH3 SCRUBBING COST IF DEDUCTION TAKEN FOR WET-LIME-STONE PROCESS COST, $/YEAR	NET FERTILIZER MFG COST USING (NH4)2SO4 FROM POWER PLANT, $/YEAR		NET FERTILIZER SALES REVENUE, $/YEAR	GROSS INCOME, $/YEAR		NET INCOME AFTER TAXES, $/YEAR		CASH FLOW, $/YEAR		CUMULATIVE CASH FLOW, $		ANNUAL RETURN ON INITIAL INVESTMENT, %	
						WITH DEDUCT	WITHOUT DEDUCT		WITH DEDUCT	WITHOUT DEDUCT	WITH DEDUCT	WITHOUT DEDUCT	WITH DEDUCT	WITHOUT DEDUCT	WITH DEDUCT	WITHOUT DEDUCT	WITH DEDUCT	WITHOUT DEDUCT
1	7000	303800	3726900	2150200	1576700	10487500	12637700	12492000	2004500	(145700)	1002250	(72850)	2560250	1485150	2560250	1485150	5.76	
2	7000	303800	3692000	2119600	1572400	10483200	12602800	12492000	2008800	(110800)	1004400	(55400)	2562400	1502600	5122650	2987750	5.78	
3	7000	303800	3657000	2089200	1567800	10478500	12567800	12492000	2013400	(75800)	1006700	(37900)	2564700	1520100	7687350	4507850	5.79	
4	7000	303800	3621900	2058700	1563200	10474000	12532700	12492000	2018000	(40700)	1009000	(20350)	2567000	1537650	10254350	6045500	5.80	
5	7000	303800	3586900	2028100	1558400	10472300	12500400	12492000	2019700	(8400)	1009850	(4200)	2567850	1553800	12822200	7599300	5.81	
6	7000	303800	3552000	1997500	1554500	10465300	12462800	12492000	2026700	29200	1013350	14600	2571350	1572600	15393550	9171900	5.83	0.08
7	7000	303800	3517000	1967100	1549900	10460700	12427800	12492000	2031300	64200	1015650	32100	2573650	1590100	17967200	10762000	5.84	0.18
8	7000	303800	3482100	1936600	1545500	10456300	12392900	12492000	2035700	99100	1017850	49550	2575850	1607550	20543050	12369550	5.85	0.29
9	7000	303800	3447000	1906000	1541000	10451800	12357800	12492000	2040200	134200	1020100	67100	2578100	1625100	23121150	13994650	5.87	0.39
10	7000	303800	3412000	1875600	1536600	10447200	12322800	12492000	2044800	169200	1022400	84600	2580400	1642600	25701550	15637250	5.88	0.49
11	5000	217000	2688500	1640100	1048400	6581100	8221200	9051000	2469900	829800	1234950	414900	1234950	414900	26936500	16052150	7.10	2.39
12	5000	217000	2653500	1610000	1043500	6576200	8186200	9051000	2474800	864800	1237400	432400	1237400	432400	28173900	16484550	7.12	2.49
13	5000	217000	2618600	1579400	1039200	6571900	8151300	9051000	2479100	899700	1239550	449850	1239550	449850	29413450	16934400	7.13	2.59
14	5000	217000	2583400	1549000	1034400	6567100	8116100	9051000	2483900	934900	1241950	467450	1241950	467450	30655400	17401850	7.14	2.69
15	5000	217000	2548500	1518400	1030100	6562800	8081200	9051000	2488200	969800	1244100	484900	1244100	484900	31899500	17886750	7.16	2.79
16	3500	151900	2144500	1311600	832900	4959700	6271300	6415000	1455300	143700	727650	71850	727650	71850	32627150	17958600	4.19	0.41
17	3500	151900	2109600	1281200	828400	4955200	6236400	6415000	1459800	178600	729900	89300	729900	89300	33357050	18047900	4.20	0.51
18	3500	151900	2074600	1250600	824000	4950800	6201400	6415000	1464200	213600	732100	106800	732100	106800	34089150	18154700	4.21	0.61
19	3500	151900	2039500	1220100	819400	4946200	6166300	6415000	1468800	248700	734400	124350	734400	124350	34823550	18279050	4.22	0.72
20	3500	151900	2004600	1189700	814900	4941700	6131400	6415000	1473300	283600	736650	141900	736650	141900	35560200	18420950	4.24	0.82
21	1500	65300	1334600	952200	382400	2541900	3494100	2820000	278100	(674100)	139050	(337050)	139050	(337050)	35699250	18083800	0.80	
22	1500	65300	1299700	921600	378100	2537600	3459200	2820000	282400	(639200)	141200	(319600)	141200	(319600)	35840450	17764200	0.81	
23	1500	65300	1264700	891100	373600	2533100	3424200	2820000	286900	(604200)	143450	(302100)	143450	(302100)	35983900	17462100	0.83	
24	1500	65300	1229600	860700	368900	2528400	3389100	2820000	291600	(569100)	145800	(284550)	145800	(284550)	36129700	17177550	0.84	
25	1500	65300	1194600	830100	364500	2524000	3354100	2820000	296000	(534100)	148000	(267050)	148000	(267050)	36277700	16910500	0.85	
26	1500	65300	1159700	799500	360200	2519700	3319200	2820000	300300	(499200)	150150	(249600)	150150	(249600)	36427850	16660900	0.86	
27	1500	65300	1124700	769200	355500	2515000	3284200	2820000	305000	(464200)	152500	(232100)	152500	(232100)	36580350	16428800	0.88	
28	1500	65300	1089800	738400	351400	2510900	3249300	2820000	309100	(429300)	154550	(214650)	154550	(214650)	36734900	16214150	0.89	
29	1500	65300	1054600	708100	346500	2506000	3214100	2820000	314000	(394100)	157000	(197050)	157000	(197050)	36891900	16017100	0.90	
30	1500	65300	1019700	677400	342300	2501800	3179200	2820000	318200	(359200)	159100	(179600)	159100	(179600)	37051000	15837500	0.92	
31	1500	65300	984800	647100	337700	2497200	3144300	2820000	322800	(324300)	161400	(162150)	161400	(162150)	37212400	15675350	0.93	
32	1500	65300	949800	616500	333300	2492800	3109300	2820000	327200	(289300)	163600	(144650)	163600	(144650)	37376000	15530700	0.94	
33	1500	65300	914900	585900	329000	2488500	3074400	2820000	331500	(254400)	165750	(127200)	165750	(127200)	37541750	15403500	0.95	
34	1500	65300	879700	555600	324100	2483600	3039200	2820000	336400	(219200)	168200	(109600)	168200	(109600)	37709950	15293900	0.97	
35	1500	65300	844800	525000	319800	2479300	3004300	2820000	340700	(184300)	170350	(92150)	170350	(92150)	37880300	15201750	0.98	
TOTAL	135000	5862000	75505800	45357100	30148700	199949400	245306500	244550000	44600600	(756500)	22300300	(378250)	37880300	15201750		AVG=	3.66	

Table B-130

PROCESS A, COOPERATIVE ECONOMICS, 500 MW., EXISTING UNIT, 3.5% S IN COAL, 20-14-0 FERTILIZER PRODUCTION

FIXED INVESTMENT = $ 16090000
TOTAL INITIAL INVESTMENT = $ 17942700
OVERALL INTEREST RATE OF RETURN WITH DEDUCT = 10.4%
OVERALL INTEREST RATE OF RETURN WITHOUT DEDUCT = NEG

YEARS REQUIRED FOR PAYOUT WITH DEDUCT: 6.4
NO PAYOUT WITHOUT DEDUCT

YEARS AFTER POWER UNIT START	ANNUAL OPERATION KW-HR/KW	TONS/YEAR FERTILIZER	TOTAL NH3 SCRUBBING OPERATING COST INCL REGUL. ROI FOR POWER CO., $/YEAR	ALTERNATE WET-LIMESTONE PROCESS AIR POLLUTION CONTROL COST, $/YEAR	NET NH3 SCRUBBING COST IF DEDUCTION TAKEN FOR WET-LIMESTONE PROCESS COST, $/YEAR	NET FERTILIZER MFG COST USING (NH4)2SO4 FROM POWER PLANT, $/YEAR		NET FERTILIZER SALES REVENUE, $/YEAR	GROSS INCOME, $/YEAR		NET INCOME AFTER TAXES, $/YEAR		CASH FLOW, $/YEAR		CUMULATIVE CASH FLOW, $		ANNUAL RETURN ON INITIAL INVESTMENT, %	
						WITH DEDUCT	WITHOUT DEDUCT		WITH DEDUCT	WITHOUT DEDUCT	WITH DEDUCT	WITHOUT DEDUCT	WITH DEDUCT	WITHOUT DEDUCT	WITH DEDUCT	WITHOUT DEDUCT	WITH DEDUCT	WITHOUT DEDUCT
1																		
2																		
3																		
4	7000	310800	3921300	2261500	1659800	10993200	13254700	12764600	1771400	(490100)	885700	(245050)	2494700	1363950	2494700	1363950	4.94	
5	7000	310800	3880800	2226100	1654700	10988100	13214200	12764600	1776500	(449600)	888250	(224800)	2497250	1384200	4991950	2748150	4.95	
6	7000	310800	3840400	2191000	1649400	10982800	13173800	12764600	1781800	(409200)	890900	(204600)	2499900	1404400	7491850	4152550	4.97	
7	7000	310800	3799900	2155600	1644300	10977700	13133300	12764600	1786900	(368700)	893450	(184350)	2502450	1424650	9994300	5577200	4.98	
8	7000	310800	3759300	2120500	1638800	10972200	13092700	12764600	1792400	(328100)	896200	(164050)	2505200	1444950	12499500	7022150	4.99	
9	7000	310800	3718700	2085100	1633600	10967000	13052100	12764600	1797600	(287500)	898800	(143750)	2507800	1465250	15007300	8487400	5.01	
10	7000	310800	3678400	2050000	1628400	10961800	13011800	12764600	1802800	(247200)	901400	(123600)	2510400	1485400	17517700	9972800	5.02	
11	5000	222000	3015500	1804000	1211500	8629700	10433700	9253000	623300	(1180700)	311650	(590350)	1920650	1018650	19438350	10991450	1.74	
12	5000	222000	2975000	1768900	1206100	8624300	10393200	9253000	628700	(1140200)	314350	(570100)	1923350	1038900	21361700	12030350	1.75	
13	5000	222000	2934600	1733500	1201100	8619300	10352800	9253000	633700	(1099800)	316850	(549900)	1925850	1059100	23287550	13089450	1.77	
14	5000	222000	2894100	1698300	1195800	7005000	8703300	9253000	2248000	549700	1124000	274850	1124000	274850	24411550	13364300	6.26	1.53
15	5000	222000	2853500	1663000	1190500	6999700	8662700	9253000	2253300	590300	1126650	295150	1126650	295150	25538200	13659450	6.28	1.64
16	3500	155400	2336000	1447600	888400	5218300	6665900	6561000	1342700	(104900)	671350	(52450)	671350	(52450)	26209550	13607000	3.74	
17	3500	155400	2295400	1412300	883100	5213000	6625300	6561000	1348000	(64300)	674000	(32150)	674000	(32150)	26883550	13574850	3.76	
18	3500	155400	2254800	1377100	877700	5207600	6584700	6561000	1353400	(23700)	676700	(11850)	676700	(11850)	27560250	13563000	3.77	
19	3500	155400	2214300	1341800	872500	5202400	6544200	6561000	1358600	16800	679300	8400	679300	8400	28239550	13571400	3.79	0.05
20	3500	155400	2173900	1306600	867300	5197200	6503800	6561000	1363800	57200	681900	28600	681900	28600	28921450	13600000	3.80	0.16
21	1500	66800	1472400	1061200	411200	2672300	3733500	2883800	211500	(849700)	[illegible]	(424850)	105750	(424850)	29027200	13175150	0.59	
22	1500	66800	1431800	1025900	405900	2667000	3692900	2883800	216800	(809100)	[illegible]	(404550)	108400	(404550)	29135600	12770600	0.60	
23	1500	66800	1391400	990700	400700	2661800	3652500	2883800	222000	(768700)	[illegible]	(384350)	111000	(384350)	29246600	12386250	0.62	
24	1500	66800	1350900	955400	395500	2656600	3612000	2883800	227200	(728200)	[illegible]	(364100)	113600	(364100)	29360200	12022150	0.63	
25	1500	66800	1310300	920200	390100	2651200	3571400	2883800	232600	(687600)	116300	(343800)	116300	(343800)	29476500	11678350	0.65	
26	1500	66800	1270000	884900	385100	2646200	3531100	2883800	237600	(647300)	118800	(323650)	118800	(323650)	29595300	11354700	0.66	
27	1500	66800	1229400	849700	379700	2640800	3490500	2883800	243000	(606700)	121500	(303350)	121500	(303350)	29716800	11051350	0.68	
28	1500	66800	1188900	814300	374600	2635700	3450000	2883800	248100	(566200)	124050	(283100)	124050	(283100)	29840850	10768250	0.69	
29	1500	66800	1148500	779200	369300	2630400	3409600	2883800	253400	(525800)	126700	(262900)	126700	(262900)	29967550	10505350	0.71	
30	1500	66800	1107900	743800	364100	2625200	3369000	2883800	258600	(485200)	129300	(242600)	129300	(242600)	30096850	10262750	0.72	
31	1500	66800	1067400	708700	358700	2619800	3328500	2883800	264000	(444700)	132000	(222350)	132000	(222350)	30228850	10040400	0.74	
32	1500	66800	1026800	673300	353500	2614600	3287900	2883800	269200	(404100)	134600	(202050)	134600	(202050)	30363450	9838350	0.75	
33	1500	66800	986500	638200	348300	2609400	3247600	2883800	274400	(363800)	137200	(181900)	137200	(181900)	30500650	9656450	0.76	
34	1500	66800	945900	602800	343100	2604200	3207000	2883800	279600	(323200)	139800	(161600)	139800	(161600)	30640450	9494850	0.78	
35	1500	66800	905400	567700	337700	2598800	3166500	2883800	285000	(282700)	142500	(141350)	142500	(141350)	30782950	9353500	0.79	
TOTAL	114000	5064600	70379400	42858900	27520500	182293300	225152200	211679200	29385900	(13473000)	14692950	(6736500)	30782950	9353500		AVG=	2.56	

Table B-131

PROCESS A. COOPERATIVE ECONOMICS, 500 MW., NEW UNIT, 5.0% S IN COAL, 28-14-0 FERTILIZER PRODUCTION

FIXED INVESTMENT = $ 19870000
TOTAL INITIAL INVESTMENT = $ 22159000
OVERALL INTEREST RATE OF RETURN WITH DEDUCT = 16.9%
OVERALL INTEREST RATE OF RETURN WITHOUT DEDUCT = 11.0%

YEARS REQUIRED FOR PAYOUT WITH DEDUCT: 4.7
YEARS REQUIRED FOR PAYOUT WITHOUT DEDUCT: 6.7

YEARS AFTER POWER UNIT START	ANNUAL OPERA-TION KW-HR/KW	TONS/YEAR FERTILIZER	TOTAL NH3 SCRUBBING OPERATING COST INCL REGUL.ROI FOR POWER CO.,$/YEAR	ALTERNAT-WET-LIME-STONE PRO-CESS AIR POLLUTION CONTROL COST, $/YEAR	NET NH3 SCRUBBING COST IF DEDUCTION TAKEN FOR WET-LIME-STONE PRO-CESS COST, $/YEAR	NET FERTILIZER MFG COST USING (NH4)2SO4 FROM POWER PLANT, $/YEAR		NET FERTILIZER SALES REVENUE, $/YEAR	GROSS INCOME, $/YEAR		NET INCOME AFTER TAXES, $/YEAR		CASH FLOW, $/YEAR		CUMULATIVE CASH FLOW, $		ANNUAL RETURN ON INITIAL INVESTMENT, %	
						WITH DEDUCT	WITHOUT DEDUCT		WITH DEDUCT	WITHOUT DEDUCT	WITH DEDUCT	WITHOUT DEDUCT	WITH DEDUCT	WITHOUT DEDUCT	WITH DEDUCT	WITHOUT DEDUCT	WITH DEDUCT	WITHOUT DEDUCT
1	7000	434000	4224500	2506500	1718000	13121200	15627700	17516200	4395000	1888500	2197500	944250	4184500	2931250	4184500	2931250	9.92	4.26
2	7000	434000	4187200	2473000	1714200	13117400	15590400	17516200	4398800	1925800	2199400	962900	4186400	2949900	8370900	5881150	9.93	4.35
3	7000	434000	4150000	2439300	1710700	13113900	15553200	17516200	4402300	1963000	2201150	981500	4188150	2968500	12559050	8849650	9.93	4.43
4	7000	434000	4112800	2405800	1707000	13110200	15516000	17516200	4406000	2000200	2203000	1000100	4190000	2987100	16749050	11836750	9.94	4.51
5	7000	434000	4075600	2372100	1703500	13106700	15478800	17516200	4409500	2037400	2204750	1018700	4191750	3005700	20940800	14842450	9.95	4.60
6	7000	434000	4038500	2338600	1699900	13103100	15441700	17516200	4413100	2074500	2206550	1037250	4193550	3024250	25134350	17866700	9.96	4.68
7	7000	434000	4001300	2304900	1696400	13099600	15404500	17516200	4416600	2111700	2208300	1055850	4195300	3042850	29329650	20909550	9.97	4.76
8	7000	434000	3964100	2271500	1692600	13095800	15367300	17516200	4420400	2148900	2210200	1074450	4197200	3061450	33526850	23971000	9.97	4.85
9	7000	434000	3926800	2238000	1688800	13092000	15330000	17516200	4424200	2186200	2212100	1093100	4199100	3080100	37725950	27051100	9.98	4.93
10	7000	434000	3889600	2204300	1685300	13088500	15292800	17516200	4427700	2223400	2213850	1111700	4200850	3098700	41926800	30149800	9.99	5.02
11	5000	309800	3140900	1903900	1237000	8328800	10232700	12726600	4397800	2493900	2198900	1246950	2198900	1246950	44125700	31396750	9.92	5.63
12	5000	309800	3103600	1870200	1233400	8325200	10195400	12726600	4401400	2531200	2200700	1265600	2200700	1265600	46326400	32662350	9.93	5.71
13	5000	309800	3066400	1836700	1229700	8321500	10159200	12726600	4405100	2568400	2202550	1284200	2202550	1284200	48528950	33946550	9.94	5.80
14	5000	309800	3029200	1803000	1226200	8318000	10121000	12726600	4408600	2605600	2204300	1302800	2204300	1302800	50733250	35249350	9.95	5.88
15	5000	309800	2991900	1769500	1222400	8314200	10083700	12726600	4412400	2642900	2206200	1321450	2206200	1321450	52939450	36570800	9.96	5.96
16	3500	217000	2410600	1512100	898500	6177100	7689200	9051000	2873900	1361800	1436950	680900	1436950	680900	54376400	37251700	6.48	3.07
17	3500	217000	2373400	1478400	895000	6173600	7652000	9051000	2877400	1399000	1438700	699500	1438700	699500	55815100	37951200	6.49	3.16
18	3500	217000	2336200	1444900	891300	6169900	7614800	9051000	2881100	1436200	1440550	718100	1440550	718100	57255650	38669300	6.50	3.24
19	3500	217000	2298900	1411300	887600	6166200	7577500	9051000	2884800	1473500	1442400	736750	1442400	736750	58698050	39406050	6.51	3.32
20	3500	217000	2261700	1377800	883900	6162500	7540300	9051000	2888500	1510700	1444250	755350	1444250	755350	60142300	40161400	6.52	3.41
21	1500	92800	1473600	1078200	395400	3143900	4222100	3977400	833500	(244700)	416750	(122350)	416750	(122350)	60559050	40039050	1.88	
22	1500	92800	1436300	1044700	391600	3140100	4184800	3977400	837300	(207400)	418650	(103700)	418650	(103700)	60977700	39935350	1.89	
23	1500	92800	1399100	1011900	387200	3135700	4147600	3977400	841700	(170200)	420850	(85100)	420850	(85100)	61398550	39850250	1.90	
24	1500	92800	1361900	977500	384400	3132900	4110400	3977400	844500	(133000)	422250	(66500)	422250	(66500)	61820800	39783750	1.91	
25	1500	92800	1324600	944000	380600	3129100	4073100	3977400	848300	(95700)	424150	(47850)	424150	(47850)	62244950	39735900	1.91	
26	1500	92800	1287400	910300	377100	3125600	4035900	3977400	851800	(58500)	425900	(29250)	425900	(29250)	62670850	39706650	1.92	
27	1500	92800	1250400	876800	373600	3122100	3998900	3977400	855300	(21500)	427650	(10750)	427650	(10750)	63098500	39695900	1.93	
28	1500	92800	1213100	843100	370000	3118500	3961600	3977400	858900	15800	429450	7900	429450	7900	63527950	39703800	1.94	0.04
29	1500	92800	1175900	809600	366300	3114800	3924400	3977400	862600	53000	431300	26500	431300	26500	63959250	39730300	1.95	0.12
30	1500	92800	1138700	776200	362500	3111000	3887200	3977400	866400	90200	433200	45100	433200	45100	64392450	39775400	1.95	0.20
31	1500	92800	1101400	742500	358900	3107400	3849900	3977400	870000	127500	435000	63750	435000	63750	64827450	39839150	1.96	0.29
32	1500	92800	1064200	708800	355400	3103900	3812700	3977400	873500	164700	436750	82350	436750	82350	65264200	39921500	1.97	0.37
33	1500	92800	1027000	675300	351700	3100200	3775500	3977400	877200	201900	438600	100950	438600	100950	65702800	40022450	1.98	0.46
34	1500	92800	989700	641800	347900	3096400	3738200	3977400	881000	239200	440500	119600	440500	119600	66143300	40142050	1.99	0.54
35	1500	92800	952500	608100	344400	3092900	3701000	3977400	884500	276400	442250	138200	442250	138200	66585550	40280250	2.00	0.62
TOTAL	135000	8366000	85779000	52610600	33168400	250279900	302890500	343711000	93431100	40820500	46715550	20410250	66585550	40280250		AVG=	6.02	2.63

Table B-132

PROCESS A, COOPERATIVE ECONOMICS, 1000 MW., NEW UNIT, 3.5% S IN COAL, 28-14-0 FERTILIZER PRODUCTION

FIXED INVESTMENT = $ 25240000
TOTAL INITIAL INVESTMENT = $ 28338400
OVERALL INTEREST RATE OF RETURN WITH DEDUCT = 19.8%
OVERALL INTEREST RATE OF RETURN WITHOUT DEDUCT = 11.8%

YEARS REQUIRED FOR PAYOUT WITH DEDUCT: 4.6
YEARS REQUIRED FOR PAYOUT WITHOUT DEDUCT: 6.5

YEARS AFTER POWER UNIT START	ANNUAL OPERATION KW-HR/KW	TONS/YEAR FERTILIZER	TOTAL NH3 SCRUBBING OPERATING COST INCL REGUL.ROI FOR POWER CO.,$/YEAR	ALTERNATE WET-LIMESTONE PROCESS AIR POLLUTION CONTROL COST, $/YEAR	NET NH3 SCRUBBING COST IF DEDUCTION TAKEN FOR WET-LIMESTONE PROCESS COST, $/YEAR	NET FERTILIZER MFG COST USING (NH4)2SO4 FROM POWER PLANT, $/YEAR		NET FERTILIZER SALES REVENUE, $/YEAR	GROSS INCOME, $/YEAR		NET INCOME AFTER TAXES, $/YEAR		CASH FLOW, $/YEAR		CUMULATIVE CASH FLOW, $		ANNUAL RETURN ON INITIAL INVESTMENT, %	
						WITH DEDUCT	WITHOUT DEDUCT		WITH DEDUCT	WITHOUT DEDUCT	WITH DEDUCT	WITHOUT DEDUCT	WITH DEDUCT	WITHOUT DEDUCT	WITH DEDUCT	WITHOUT DEDUCT	WITH DEDUCT	WITHOUT DEDUCT
1	7000	587500	5936700	3362400	2574300	17306900	20669300	23270900	5964000	2601600	2982000	1300800	5506000	3824800	5506000	3824800	10.52	4.59
2	7000	587500	5881600	3317000	2564600	17297200	20614200	23270900	5973700	2656700	2986850	1328350	5510850	3852350	11016850	7677150	10.54	4.69
3	7000	587500	5826600	3271900	2554700	17287300	20559200	23270900	5983600	2711700	2991800	1355850	5515800	3879850	16532650	11557000	10.56	4.78
4	7000	587500	5771500	3226500	2545000	17277600	20504100	23270900	5993300	2766800	2996650	1383400	5520650	3907400	22053300	15464400	10.57	4.88
5	7000	587500	5716600	3181200	2535400	17268000	20449200	23270900	6002900	2821700	3001450	1410850	[illegible]	3934850	27578750	19399250	10.59	4.98
6	7000	587500	5661500	3135800	2525700	17258300	20394100	23270900	6012600	2876800	3006300	1438400	[illegible]	3962400	33109050	23361650	10.61	5.08
7	7000	587500	5606400	3090700	2515700	17248300	20339000	23270900	6022600	2931900	3011300	1465950	[illegible]	3989950	38644350	27351600	10.63	5.17
8	7000	587500	5551500	3045600	2506100	17238700	20284100	23270900	6032200	2986800	3016100	1493400	5540100	4017400	44184450	31369000	10.64	5.27
9	7000	587500	5496300	3000000	2496300	17228900	20228900	23270900	6042000	3042000	3021000	1521000	5545000	4045000	49729450	35414000	10.66	5.37
10	7000	587500	5441400	2954900	2486500	17219100	20174000	23270900	6051800	3096900	3025900	1548450	5549900	4072450	55279350	39486450	10.68	5.46
11	5000	419700	4420200	2565100	1855100	11017700	13582800	16972700	5955000	3389900	2977500	1694950	2977500	1694950	58256850	41181400	10.51	5.98
12	5000	419700	4365100	2519800	1845300	11007900	13527700	16972700	5964800	3445000	2982400	1722500	2982400	1722500	61239250	42903900	10.52	6.08
13	5000	419700	4310200	2474500	1835700	10998300	13472800	16972700	5974400	3499900	2987200	1749950	2987200	1749950	64226450	44653850	10.54	6.18
14	5000	419700	4255100	2429300	1825800	10988400	13417700	16972700	5984300	3555000	2992150	1777500	2992150	1777500	67218600	46431350	10.56	6.27
15	5000	419700	4200100	2384000	1816100	10978700	13362700	16972700	5994000	3610000	2997000	1805000	2997000	1805000	70215600	48236350	10.58	6.37
16	3500	293800	3404400	2053500	1350900	8151900	10205400	12098700	3946800	1893300	1973400	946650	1973400	946650	72189000	49183000	6.96	3.34
17	3500	293800	3349300	2008400	1340900	8141900	10150300	12098700	3956800	1948400	1978400	974200	1978400	974200	74167400	50157200	6.98	3.44
18	3500	293800	3294400	1963100	1331300	8132300	10095400	12098700	3966400	2003300	1983200	1001650	1983200	1001650	76150600	51158850	7.00	3.53
19	3500	293800	3239300	1917700	1321600	8122600	10040300	12098700	3976100	2058400	1988050	1029200	1988050	1029200	78138650	52188050	7.02	3.63
20	3500	293800	3184400	1872400	1312000	8113000	9985400	12098700	3985700	2113500	1992850	1056650	1992850	1056650	80131500	53244700	7.03	3.73
21	1500	126300	2106700	1496500	610200	3934700	5431200	5366500	1431800	(64700)	715900	(32350)	715900	(32350)	80847400	53212350	2.53	
22	1500	126300	2051600	1451200	600400	3924900	5376100	5366500	1441600	(9600)	720800	(4800)	720800	(4800)	81568200	53207550	2.54	
23	1500	126300	1996700	1405800	590900	3915400	5321200	5366500	1451100	45300	725550	22650	725550	22650	82293750	53230200	2.56	0.08
24	1500	126300	1941600	1360700	580900	3905600	5266100	5366500	1461100	100400	730550	50200	730550	50200	83024300	53280400	2.58	0.18
25	1500	126300	1886700	1315400	571300	3895800	5211200	5366500	1470700	155300	735350	77650	735350	77650	83759650	53358050	2.59	0.27
26	1500	126300	1831600	1270000	561600	3886100	5156100	5366500	1480400	210400	740200	105200	740200	105200	84499850	53463250	2.61	0.37
27	1500	126300	1776400	1224700	551700	3876200	5100900	5366500	1490300	265500	745150	132800	745150	132800	85245000	53596050	2.63	0.47
28	1500	126300	1721500	1179500	542000	3866500	5046000	5366500	1500000	320500	750000	160250	750000	160250	85995000	53756300	2.65	0.57
29	1500	126300	1666400	1134200	532200	3856700	4990900	5366500	1509800	375600	754900	187800	754900	187800	86749900	53944100	2.66	0.66
30	1500	126300	1611500	1088800	522700	3847200	4936000	5366500	1519300	430500	759650	215250	759650	215250	87509550	54159350	2.68	0.76
31	1500	126300	1556400	1043700	512700	3837200	4880900	5366500	1529300	485600	764650	242800	764650	242800	88274200	54402150	2.70	0.86
32	1500	126300	1501300	998400	502900	3827400	4825800	5366500	1539100	540700	769550	270350	769550	270350	89043750	54672500	2.72	0.95
33	1500	126300	1446300	953000	493300	3817800	4770800	5366500	1548700	595700	774350	297850	774350	297850	89818100	54970350	2.73	1.05
34	1500	126300	1391200	907700	483500	3808000	4715700	5366500	1558500	650800	779250	325400	779250	325400	90597350	55295750	2.75	1.15
35	1500	126300	1336300	862500	473800	3798300	4660800	5366500	1568200	705700	784100	352850	784100	352850	91381450	55648600	2.77	1.25
TOTAL	135000	11337000	120734800	71465700	49269100	326280600	397746300	458563500	132282900	60817200	64141450	30408600	91381450	55648600		AVG=	6.67	3.07

Table B-133

PROCESS A, COOPERATIVE ECONOMICS, 1000 MW., EXISTING UNIT, 3.5% S IN COAL, 28-14-0 FERTILIZER PRODUCTION

FIXED INVESTMENT = $ 26660000
TOTAL INITIAL INVESTMENT = $ 29873000
OVERALL INTEREST RATE OF RETURN WITH DEDUCT = 17.5%
OVERALL INTEREST RATE OF RETURN WITHOUT DEDUCT = 8.3%

YEARS REQUIRED FOR PAYOUT WITH DEDUCT: 4.8
YEARS REQUIRED FOR PAYOUT WITHOUT DEDUCT: 6.9

YEARS AFTER POWER UNIT START	ANNUAL OPERA-TION KW-HR/KW	TONS/YEAR FERTILIZER	TOTAL NH3 SCRUBBING OPERATING COST INCL REGUL.ROI FOR POWER CO.,$/YEAR	ALTERNATE WET-LIME-STONE PRO-CESS AIR POLLUTION CONTROL COST, $/YEAR	NET NH3 SCRUBBING COST IF DEDUCTION TAKEN FOR WET-LIME-STONE PRO-CESS COST, $/YEAR	NET FERTILIZER MFG COST USING (NH4)2SO4 FROM POWER PLANT, $/YEAR		NET FERTILIZER SALES REVENUE, $/YEAR	GROSS INCOME, $/YEAR		NET INCOME AFTER TAXES, $/YEAR		CASH FLOW, $/YEAR		CUMULATIVE CASH FLOW, $		ANNUAL RETURN ON INITIAL INVESTMENT, %	
						WITH DEDUCT	WITHOUT DEDUCT		WITH DEDUCT	WITHOUT DEDUCT	WITH DEDUCT	WITHOUT DEDUCT	WITH DEDUCT	WITHOUT DEDUCT	WITH DEDUCT	WITHOUT DEDUCT	WITH DEDUCT	WITHOUT DEDUCT
1																		
2																		
3																		
4	7000	607600	6390300	3587300	2803000	18232600	21819900	24018400	5785800	2198500	2892900	1099250	5558900	3765250	5558900	3765250	9.66	3.68
5	7000	607600	6326000	3533800	2792200	18221800	21755600	24018400	5796600	2262800	2898300	1131400	5564300	3797400	11123200	7562650	9.70	3.79
6	7000	607600	6261800	3480600	2781200	18210800	21691400	24018400	5807600	2327000	2903800	1163500	5569800	3829500	16693000	11392150	9.72	3.89
7	7000	607600	6197500	3427200	2770300	18199900	21627100	24018400	5818500	2391300	2909250	1195650	5575250	3861650	22268250	15253800	9.74	4.00
8	7000	607600	6133200	3373900	2759300	18188900	21562800	24018400	5829500	2455600	2914750	1227800	5580750	3893800	27849000	19147600	9.76	4.11
9	7000	607600	6069000	3319900	2749100	18178700	21498600	24018400	5839700	2519800	2919850	1259900	5585850	3925900	33434850	23073500	9.77	4.22
10	7000	607600	6004500	3267200	2737300	18166900	21434100	24018400	5851500	2584300	2925750	1292150	5591750	3958150	39026600	27031650	9.79	4.33
11	5000	433800	4911200	2857000	2054200	14263700	17120700	17508200	3244500	387500	1622250	193750	4288250	2859750	43314850	29891400	5.43	0.65
12	5000	433800	4846900	2803800	2043100	14252600	17056400	17508200	3255600	451800	1627800	225900	4293800	2891900	47608650	32783300	5.45	0.76
13	5000	433800	4782700	2750300	2032400	14241900	16992200	17508200	3266300	516000	1633150	258000	4299150	2924000	51907800	35707300	5.47	0.86
14	5000	433800	4718400	2696900	2021500	11565000	14261900	17508200	5943200	3246300	2971600	1623150	2971600	1623150	54879400	37330450	9.95	5.43
15	5000	433800	4654100	2643600	2010500	11554000	14197600	17508200	5954200	3310600	2977100	1655300	2977100	1655300	57856500	38985750	9.97	5.54
16	3500	303700	3797800	2294300	1503500	8561700	10856000	12488100	3926400	1632100	1963200	816050	1963200	816050	59819700	39801800	6.57	2.73
17	3500	303700	3733600	2241100	1492500	8550700	10791900	12488100	3937400	1696300	1968700	848150	1968700	848150	61788400	40649950	6.59	2.84
18	3500	303700	3669300	2187600	1481700	8539900	10727500	12488100	3948200	1760600	1974100	880300	1974100	880300	63762500	41530250	6.61	2.95
19	3500	303700	3605000	2134400	1470600	8528800	10663200	12488100	3959300	1824900	1979650	912450	1979650	912450	65742150	42442700	6.63	3.05
20	3500	303700	3540600	2080900	1459700	8517900	10598800	12488100	3970200	1889300	1985100	944650	1985100	944650	67727250	43387350	6.65	3.16
21	1500	130100	2379300	1685300	694000	4321200	6006500	5522700	1201500	(483800)	600750	(241900)	600750	(241900)	68328000	43145450	2.01	
22	1500	130100	2315000	1632000	683000	4310200	5942200	5522700	1212500	(419500)	606250	(209750)	606250	(209750)	68934250	42935700	2.03	
23	1500	130100	2250700	1578600	672100	4299300	5877900	5522700	1223400	(355200)	611700	(177600)	611700	(177600)	69545950	42758100	2.05	
24	1500	130100	2186500	1525300	661200	4288400	5813700	5522700	1234300	(291000)	617150	(145500)	617150	(145500)	70163100	42612600	2.07	
25	1500	130100	2122200	1471900	650300	4277500	5749400	5522700	1245200	(226700)	622600	(113350)	622600	(113350)	70785700	42499250	2.08	
26	1500	130100	2057900	1418600	639300	4266500	5685100	5522700	1256200	(162400)	628100	(81200)	628100	(81200)	71413800	42418050	2.10	
27	1500	130100	1993600	1365200	628400	4255600	5620800	5522700	1267100	(98100)	633550	(49050)	633550	(49050)	72047350	42369000	2.12	
28	1500	130100	1929400	1311900	617500	4244700	5556600	5522700	1278000	(33900)	639000	(16950)	639000	(16950)	72686350	42352050	2.14	
29	1500	130100	1865100	1258500	606600	4233800	5492300	5522700	1288900	30400	644450	15200	644450	15200	73330800	42367250	2.16	0.05
30	1500	130100	1800600	1205000	595600	4222800	5427800	5522700	1299900	94900	649950	47450	649950	47450	73980750	42414700	2.18	0.16
31	1500	130100	1736400	1151800	584600	4211800	5363600	5522700	1310900	159100	655450	79550	655450	79550	74636200	42494250	2.19	0.27
32	1500	130100	1672100	1098300	573800	4201000	5299300	5522700	1321700	223400	660850	111700	660850	111700	75297050	42605950	2.21	0.37
33	1500	130100	160[illegible]	1045100	562700	4189900	5235000	5522700	1332800	287700	666400	143850	666400	143850	75963450	42749800	2.23	0.48
34	1500	130100	1543500	991600	551900	4179100	5170700	5522700	1343600	352000	671800	176000	671800	176000	76635750	42925800	2.25	0.59
35	1500	130100	1479300	938400	540900	4168100	5106500	5522700	1354600	416200	677300	208100	677300	208100	77312550	43133900	2.27	0.70
TOTAL	114000	9892200	114581300	68357300	46224000	299645700	368003000	400950800	101305100	32947800	50652550	16473900	77312550	43133900		AVG=	5.30	1.72

Table B-134

PROCESS B, COOPERATIVE ECONOMICS, 200 MW., EXISTING UNIT, 3.5% S IN COAL, 26-19-0 FERTILIZER PRODUCTION

FIXED INVESTMENT = $ 8794000
TOTAL INITIAL INVESTMENT = $ 9635000
OVERALL INTEREST RATE OF RETURN WITH DEDUCT = NEG
OVERALL INTEREST RATE OF RETURN WITHOUT DEDUCT = NEG

NO PAYOUT WITH DEDUCT
NO PAYOUT WITHOUT DEDUCT

YEARS AFTER POWER UNIT START	ANNUAL OPERATION KW-HR/KW	TONS/YEAR FERTILIZER	TOTAL NH3 SCRUBBING OPERATING COST INCL REGUL.ROI FOR POWER CO., $/YEAR	ALTERNATE WET-LIMESTONE PROCESS AIR POLLUTION CONTROL COST, $/YEAR	NET NH3 SCRUBBING COST IF DEDUCTION TAKEN FOR WET-LIMESTONE PROCESS COST, $/YEAR	NET FERTILIZER MFG COST USING (NH4)2SO4 FROM POWER PLANT, $/YEAR		NET FERTILIZER SALES REVENUE, $/YEAR	GROSS INCOME, $/YEAR		NET INCOME AFTER TAXES, $/YEAR		CASH FLOW, $/YEAR		CUMULATIVE CASH FLOW, $		ANNUAL RETURN ON INITIAL INVESTMENT, %	
						WITH DEDUCT	WITHOUT DEDUCT		WITH DEDUCT	WITHOUT DEDUCT	WITH DEDUCT	WITHOUT DEDUCT	WITH DEDUCT	WITHOUT DEDUCT	WITH DEDUCT	WITHOUT DEDUCT	WITH DEDUCT	WITHOUT DEDUCT
1																		
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9	7000	97100	1422400	1087900	334500	4517700	5605600	4386000	(131700)	(1219600)	(65850)	(609800)	813550	269600	813550	269600		
10	7000	97100	1402200	1067700	334500	4517700	5585400	4386000	(131700)	(1199400)	(65850)	(599700)	813550	279700	1627100	549300		
11	5000	69500	1192300	947100	245200	3659300	4606400	3162300	(497000)	(1444100)	(248500)	(722050)	630900	157350	2258000	706650		
12	5000	69500	1171900	927000	244900	3659000	4586000	3162300	(496700)	(1423700)	(248350)	(711850)	631050	167550	2889050	874200		
13	5000	69500	1151700	906800	244900	3659000	4565800	3162300	(496700)	(1403500)	(248350)	(701750)	631050	177650	3520100	1051850		
14	5000	69500	1131400	886600	244800	3658900	4545500	3162300	(496600)	(1383200)	(248300)	(691600)	631100	187800	4151200	1239650		
15	5000	69500	1111200	866400	244800	3658900	4525300	3162300	(496600)	(1363000)	(248300)	(681500)	631100	197900	4782300	1437550		
16	3500	48600	943600	762900	180700	2992200	3755100	2225400	(766800)	(1529700)	(383400)	(764850)	496000	114550	5278300	1552100		
17	3500	48600	923400	742800	180600	2992100	3734900	2225400	(766700)	(1509500)	(383350)	(754750)	496050	124650	5774350	1676750		
18	3500	48600	903000	722600	180400	2991900	3714500	2225400	(766500)	(1489100)	(383250)	(744550)	496150	134850	6270500	1811600		
19	3500	48600	882900	702400	180500	2112600	2815000	2225400	112800	(589600)	56400	(294800)	56400	(294800)	6326900	1516800	0.59	
20	3500	48600	862300	682200	180100	2112200	2794400	2225400	113200	(569000)	56600	(284500)	56600	(284500)	6383500	1232300	0.59	
21	1500	20800	633200	553000	80200	1147300	1700300	963000	(184300)	(737300)	(92150)	(368650)	(92150)	(368650)	6291350	863650		
22	1500	20800	613000	532800	80200	1147300	1680100	963000	(184300)	(717100)	(92150)	(358550)	(92150)	(358550)	6199200	505100		
23	1500	20800	592800	512600	80200	1147300	1659900	963000	(184300)	(696900)	(92150)	(348450)	(92150)	(348450)	6107050	156650		
24	1500	20800	572500	492400	80100	1147200	1639600	963000	(184200)	(676600)	(92100)	(338300)	(92100)	(338300)	6014950	(181650)		
25	1500	20800	552300	472300	80000	1147100	1619400	963000	(184100)	(656400)	(92050)	(328200)	(92050)	(328200)	5922900	(509850)		
26	1500	20800	531900	452100	79800	1146900	1599000	963000	(183900)	(636000)	(91950)	(318000)	(91950)	(318000)	5830950	(827850)		
27	1500	20800	511700	431900	79800	1146900	1578800	963000	(183900)	(615800)	(91950)	(307900)	(91950)	(307900)	5739000	(1135750)		
28	1500	20800	491300	411700	79600	1146700	1558400	963000	(183700)	(595400)	(91850)	(297700)	(91850)	(297700)	5647150	(1433450)		
29	1500	20800	471200	391600	79600	1146700	1538300	963000	(183700)	(575300)	(91850)	(287650)	(91850)	(287650)	5555300	(1721100)		
30	1500	20800	450800	371400	79400	1146500	1517900	963000	(183500)	(554900)	(91750)	(277450)	(91750)	(277450)	5463550	(1998550)		
31	1500	20800	430600	351200	79400	1146500	1497700	963000	(183500)	(534700)	(91750)	(267350)	(91750)	(267350)	5371800	(2265900)		
32	1500	20800	410200	331000	79200	1146300	1477300	963000	(183300)	(514300)	(91650)	(257150)	(91650)	(257150)	5280150	(2523050)		
33	1500	20800	390100	310900	79200	1146300	1457200	963000	(183300)	(494200)	(91650)	(247100)	(91650)	(247100)	5188500	(2770150)		
34	1500	20800	369800	290700	79100	1067100	1357800	963000	(104100)	(394800)	(52050)	(197400)	(52050)	(197400)	5136450	(2967550)		
35	1500	20800	349500	270500	79000	1067100	1337600	963000	(104100)	(374600)	(52050)	(187300)	(52050)	(187300)	5084400	(3154850)		
TOTAL	79000	1096700	20469200	16478500	3990700	57574700	74053200	50155500	(7419200)	(23897700)	(3709600)	(11948850)	5084400	(3154850)		AVG=		

Table B-135

PROCESS R, COOPERATIVE ECONOMICS, 500 MW., NEW UNIT, 2.0% S IN COAL, 26-19-0 FERTILIZER PRODUCTION

FIXED INVESTMENT = $ 10194000
TOTAL INITIAL INVESTMENT = $ 11310400
OVERALL INTEREST RATE OF RETURN WITH DEDUCT = 4.4%
OVERALL INTEREST RATE OF RETURN WITHOUT DEDUCT = NEG

YEARS REQUIRED FOR PAYOUT WITH DEDUCT: 9.0
NO PAYOUT WITHOUT DEDUCT

YEARS AFTER POWER UNIT START	ANNUAL OPERA-TION KW-HR/KW	TONS/YEAR FERTILIZER	TOTAL NH3 SCRUBBING OPERATING COST INCL REGUL.ROI FOR POWER CO.,$/YEAR	ALTERNATE WET-LIME-STONE PRO-CESS AIR POLLUTION CONTROL COST, $/YEAR	NET NH3 SCRUBBING COST IF DEDUCTION TAKEN FOR WET-LIME-STONE PRO-CESS COST, $/YEAR	NET FERTILIZER MFG COST USING (NH4)2SO4 FROM POWER PLANT, $/YEAR WITH DEDUCT	NET FERTILIZER MFG COST USING (NH4)2SO4 FROM POWER PLANT, $/YEAR WITHOUT DEDUCT	NET FERTILIZER SALES REVENUE, $/YEAR	GROSS INCOME, $/YEAR WITH DEDUCT	GROSS INCOME, $/YEAR WITHOUT DEDUCT	NET INCOME AFTER TAXES, $/YEAR WITH DEDUCT	NET INCOME AFTER TAXES, $/YEAR WITHOUT DEDUCT	CASH FLOW, $/YEAR WITH DEDUCT	CASH FLOW, $/YEAR WITHOUT DEDUCT	CUMULATIVE CASH FLOW, $ WITH DEDUCT	CUMULATIVE CASH FLOW, $ WITHOUT DEDUCT	ANNUAL RETURN ON INITIAL INVESTMENT, % WITH DEDUCT	ANNUAL RETURN ON INITIAL INVESTMENT, % WITHOUT DEDUCT
1	7000	131500	2504300	1800000	704300	5682600	7482600	5896500	213900	(1 86100)	106950	(793050)	1126350	226350	1126350	226350	0.95	
2	7000	131500	2472300	1772800	699500	5677800	7450600	5896500	218700	(1 54100)	109350	(770050)	1128750	242350	2255100	468700	0.97	
3	7000	131500	2441100	1749100	692000	5670300	7419400	5896500	226200	(1522900)	113100	(761450)	1132500	257950	3387600	726650	1.00	
4	7000	131500	2408200	1718800	689400	5667700	7386500	5896500	228800	(1490000)	114400	(745000)	1133800	274400	4521400	1001050	1.01	
5	7000	131500	2376200	1690600	685600	5663900	7354500	5896500	232600	(1458000)	116300	(729000)	1135700	290400	5657100	1291450	1.03	
6	7000	131500	2344200	1663400	680800	5659100	7322500	5896500	237400	(1426000)	118700	(713000)	1138100	306400	6795200	1597850	1.05	
7	7000	131500	2312100	1635900	676200	5654500	7290400	5896500	242000	(1393900)	121000	(696950)	1140400	322450	7935600	1920300	1.07	
8	7000	131500	2280100	1608700	671400	5649700	7258400	5896500	246800	(1361900)	123400	(680950)	1142800	338450	9078400	2258750	1.09	
9	7000	131500	2248100	1581200	666900	5645200	7226400	5896500	251300	(1329900)	125650	(664950)	1145050	354450	10223450	2613200	1.11	
10	7000	131500	2216100	1553800	662300	5640600	7194400	5896500	255900	(1297900)	127950	(648950)	1147350	370450	11370800	2983650	1.13	
11	5000	93900	1893100	1379800	513300	3532700	4912500	4246200	713500	(666300)	356750	(333150)	356750	(333150)	11727550	2650500	3.15	
12	5000	93900	1861100	1352300	508800	3528200	4880500	4246200	718000	(634300)	359000	(317150)	359000	(317150)	12086550	2333350	3.17	
13	5000	93900	1829000	1325100	503900	3523300	4848400	4246200	722900	(602200)	361450	(301100)	361450	(301100)	12448000	2032250	3.20	
14	5000	93400	1797000	1297900	499100	3518500	4816400	4246200	727700	(570200)	363850	(285100)	363850	(285100)	12811850	1747150	3.22	
15	5000	93900	1765000	1270400	494600	3514000	4784400	4246200	732200	(538200)	366100	(269100)	366100	(269100)	13177950	1478050	3.24	
16	3500	65800	1505700	1114100	391600	2678800	3792900	2997200	318400	(795700)	159200	(397850)	159200	(397850)	13337150	1080200	1.41	
17	3500	65800	1473600	1086700	386900	2674100	3760800	2997200	323100	(763600)	161550	(381800)	161550	(381800)	13498700	698400	1.43	
8	3500	65800	1441600	1059200	382400	2669600	3728800	2997200	327600	(731600)	163800	(365800)	163800	(365800)	13662500	332600	1.45	
19	3500	65800	1409600	1032000	377600	2664800	3696800	2997200	332400	(699600)	166200	(349800)	166200	(349800)	13828700	(17200)	1.47	
20	3500	65800	1377500	1004500	373000	2660200	3664700	2997200	337000	(667500)	168500	(333750)	168500	(333750)	13997200	(350950)	1.49	
21	1500	28200	1021900	827100	194800	1640100	2267200	1301400	(138700)	(965800)	(69350)	(482900)	(69350)	(482900)	13927850	(833850)		
22	1500	28200	989900	799800	190100	1435400	2235200	1301400	(134000)	(933800)	(67000)	(466900)	(67000)	(466900)	13860850	(1300750)		
23	1500	28200	957900	772400	185900	1430800	2203200	1301400	(129400)	(901800)	(64700)	(450900)	(64700)	(450900)	13796150	(1751650)		
24	1500	28200	925800	745100	180700	1426000	2171100	1301400	(124600)	(869700)	(62300)	(434850)	(62300)	(434850)	13733850	(2186500)		
25	1500	28200	893800	717700	176100	1421400	2139100	1301400	(120000)	(837700)	(60000)	(418850)	(60000)	(418850)	13673850	(2605350)		
26	1500	28200	861700	690400	171300	1416600	2107000	1301400	(115200)	(805600)	(57600)	(402800)	(57600)	(402800)	13616250	(3008150)		
27	1500	28200	829700	663000	166700	1412000	2075000	1301400	(110600)	(773600)	(55300)	(386800)	(55300)	(386800)	13560950	(3394950)		
28	1500	28200	797700	635500	162200	1407500	2043000	1301400	(106100)	(741600)	(53050)	(370800)	(53050)	(370800)	13507900	(3765750)		
29	1500	28200	765600	608300	157300	1402600	2010900	1301400	(101200)	(709500)	(50600)	(354750)	(50600)	(354750)	13457300	(4120500)		
30	1500	28200	733600	580800	152800	1398100	1978900	1301400	(96700)	(677500)	(48350)	(338750)	(48350)	(338750)	13408950	(4459250)		
31	1500	28200	701500	553600	148000	1393300	1946900	1301400	(91900)	(645500)	(45950)	(322750)	(45950)	(322750)	13363000	(4782000)		
32	1500	28200	669500	526100	143400	1388700	1914800	1301400	(87300)	(613400)	(43650)	(306700)	(43650)	(306700)	13319350	(5088700)		
33	1500	28200	637500	498900	138600	1383900	1882800	1301400	(82500)	(581400)	(41250)	(290700)	(41250)	(290700)	13278100	(5379400)		
34	1500	28200	605500	471400	134100	1379400	1850800	1301400	(78000)	(549400)	(39000)	(274700)	(39000)	(274700)	13239100	(5654100)		
35	1500	28200	573500	444200	129300	1374600	1818800	1301400	(73200)	(517400)	(36600)	(258700)	(36600)	(258700)	13202500	(5912800)		
TOTAL	135000	2536500	51921100	38230600	13690500	108686000	146916600	114703000	6017000	(32213600)	3008500	(16106800)	13202500	(5912800)		AVG=	0.76	

Table B-136

PROCESS B, COOPERATIVE ECONOMICS, 500 MW., NEW UNIT, 3.5% S IN COAL, 26-19-0 FERTILIZER PRODUCTION

FIXED INVESTMENT = $ 14128000
TOTAL INITIAL INVESTMENT = $ 15933500
OVERALL INTEREST RATE OF RETURN WITH DEDUCT = 11.9%
OVERALL INTEREST RATE OF RETURN WITHOUT DEDUCT = NEG

YEARS REQUIRED FOR PAYOUT WITH DEDUCT: 6.4
NO PAYOUT WITHOUT DEDUCT

YEARS AFTER POWER UNIT START	ANNUAL OPERATION KW-HR/KW	TONS/YEAR FERTILIZER	TOTAL NH3 SCRUBBING OPERATING COST INCL REGUL.ROI FOR POWER CO.,$/YEAR	ALTERNATE WET-LIMESTONE PROCESS AIR POLLUTION CONTROL COST, $/YEAR	NET NH3 SCRUBBING COST IF DEDUCTION TAKEN FOR WET-LIMESTONE PROCESS COST, $/YEAR	NET FERTILIZER MFG COST USING (NH4)2SO4 FROM POWER PLANT, $/YEAR		NET FERTILIZER SALES REVENUE, $/YEAR	GROSS INCOME, $/YEAR		NET INCOME AFTER TAXES, $/YEAR		CASH FLOW, $/YEAR		CUMULATIVE CASH FLOW, $		ANNUAL RETURN ON INITIAL INVESTMENT, %	
						WITH DEDUCT	WITHOUT DEDUCT		WITH DEDUCT	WITHOUT DEDUCT	WITH DEDUCT	WITHOUT DEDUCT	WITH DEDUCT	WITHOUT DEDUCT	WITH DEDUCT	WITHOUT DEDUCT	WITH DEDUCT	WITHOUT DEDUCT
1	7000	230000	3003700	2150200	853500	8542500	10692700	10129200	1586700	(563500)	793350	(281750)	2206150	1131050	2206150	1131050	4.98	
2	7000	230000	2970600	2119600	851000	8540000	10659600	10129200	1589200	(530400)	794600	(265200)	2207400	1147600	4413550	2278650	4.99	
3	7000	230000	2937500	2089200	848300	8537300	10626500	10129200	1591900	(497300)	795950	(248650)	2208750	1164150	6622300	3442800	5.00	
4	7000	230000	2904500	2058700	845800	8534800	10593500	10129200	1594400	(464300)	797200	(232150)	2210000	1180650	8832300	4623450	5.00	
5	7000	230000	2871400	2028100	843300	8532300	10560400	10129200	1596900	(431200)	798450	(215600)	2211250	1197200	11043550	5820650	5.01	
6	7000	230000	2838300	1997500	840800	8529800	10527300	10129200	1599400	(398100)	799700	(199050)	2212500	1213750	13256050	7034400	5.02	
7	7000	230000	2805300	1967100	838200	8527200	10494300	10129200	1602000	(365100)	801000	(182550)	2213800	1230250	15469850	8264650	5.03	
8	7000	230000	2772200	1936600	835600	8524600	10461200	10129200	1604600	(332000)	802300	(166000)	2215100	1246900	17684950	9511450	5.04	
9	7000	230000	2739100	1906000	833100	8522100	10428100	10129200	1607100	(298900)	803550	(149450)	2216350	1263350	19901300	10774800	5.04	
10	7000	230000	2706000	1875600	830400	8519400	10395000	10129200	1609800	(265800)	804900	(132900)	2217700	1279900	22119000	12054700	5.05	
11	5000	164300	2239400	1640100	599300	5341700	6981800	7317900	1976200	336100	988100	168050	988100	168050	23107100	12222750	6.20	1.05
12	5000	164300	2206300	1610000	596300	5338700	6948700	7317900	1979200	369200	989600	184600	989600	184600	24096700	12407350	6.21	1.16
13	5000	164300	2173200	1579400	593800	5336200	6915600	7317900	1981700	402300	990850	201150	990850	201150	25087550	12608500	6.22	1.26
14	5000	164300	2140200	1549000	591200	5333600	6882600	7317900	1984300	435300	992150	217650	992150	217650	26079700	12826150	6.23	1.37
15	5000	164300	2107100	1518400	588700	5331100	6849500	7317900	1986800	468400	993400	234200	993400	234200	27073100	13060350	6.23	1.47
16	3500	115000	1754300	1311600	442700	3996900	5308500	5173900	1177000	(134600)	588500	(67300)	588500	(67300)	27661600	12993050	3.69	
17	3500	115000	1721200	1281200	440000	3994200	5275400	5173900	1179700	(101500)	589850	(50750)	589850	(50750)	28251450	12942300	3.70	
18	3500	115000	1688200	1[illegible]0600	437600	3991800	5242400	5173900	1182100	(68500)	591050	(34250)	591050	(34250)	28842500	12908050	3.71	
19	3500	115000	1655100	1220100	435000	3989200	5209300	5173900	1184700	(35400)	592350	(17700)	592350	(17700)	29434850	12890350	3.72	
20	3500	115000	1622000	1189700	432300	3986500	5176200	5173900	1187400	(2300)	593700	(1150)	593700	(1150)	30028550	12889200	3.73	
21	1500	49300	1141900	952200	189600	2115700	3067900	2257000	141300	(810900)	70650	(405450)	70650	(405450)	30099200	12483750	0.44	
22	1500	49300	1108800	921600	187200	2113300	3034900	2257000	143700	(777900)	71850	(388950)	71850	(388950)	30171050	12094800	0.45	
23	1500	49300	1075700	891100	184600	2110700	3001400	2257000	146300	(744800)	73150	(372400)	73150	(372400)	30244200	11722400	0.46	
24	1500	49300	1042600	860700	181900	2108000	2968700	2257000	149000	(711700)	74500	(355850)	74500	(355850)	30318700	11366550	0.47	
25	1500	49300	1009600	830100	179500	2105600	2935700	2257000	151400	(678700)	75700	(339350)	75700	(339350)	30394400	11027200	0.48	
26	1500	49300	976500	799500	177000	2103100	2902600	2257000	153900	(645600)	76950	(322800)	76950	(322800)	30471350	10704400	0.48	
27	1500	49300	943400	769200	174200	2100300	2869500	2257000	156700	(612500)	78350	(306250)	78350	(306250)	30549700	10398150	0.49	
28	1500	49300	910300	738400	171900	2098000	2836400	2257000	159000	(579600)	79500	(289700)	79500	(289700)	30629200	10109450	0.50	
29	1500	49300	877300	708100	169200	2095300	2803400	2257000	161700	(546400)	80850	(273200)	80850	(273200)	30710050	9835250	0.51	
30	1500	49300	844200	677400	166800	2092900	2770300	2257000	164100	(513300)	82050	(256650)	82050	(256650)	30792100	9578600	0.51	
31	1500	49300	811100	647100	164000	2090100	2737200	2257000	166900	(480200)	83450	(240100)	83450	(240100)	30875550	9334500	0.52	
32	1500	49300	778100	616500	161600	2087700	2704200	2257000	169300	(447200)	84650	(223600)	84650	(223600)	30960200	9114900	0.53	
33	1500	49300	745000	585900	159100	2085200	2671100	2257000	171800	(414100)	85900	(207050)	85900	(207050)	31046100	8907850	0.54	
34	1500	49300	711900	555600	156300	2082400	2638000	2257000	174600	(381000)	87300	(190500)	87300	(190500)	31133400	8717350	0.55	
35	1500	49300	678800	525000	153800	2079900	2604900	2257000	177100	(347900)	88550	(173950)	88550	(173950)	31221950	8543400	0.56	
TOTAL	135000	4436000	61510700	45357100	16153600	163418100	208775200	197606000	34187900	(11169200)	17093950	(5584600)	31221950	8543400		AVG=	3.07	

Table B-137

PROCESS B, COOPERATIVE ECONOMICS, 500 MW., EXISTING UNIT, 3.5% S IN COAL, 26-19-0 FERTILIZER PRODUCTION

FIXED INVESTMENT = $ 14331000
TOTAL INITIAL INVESTMENT = $ 16183700
OVERALL INTEREST RATE OF RETURN WITH DEDUCT = 10.1%
OVERALL INTEREST RATE OF RETURN WITHOUT DEDUCT = NEG

YEARS REQUIRED FOR PAYOUT WITH DEDUCT: 6.5
NO PAYOUT WITHOUT DEDUCT

YEARS AFTER POWER UNIT START	ANNUAL OPERATION KW-HR/KW	TONS/YEAR FERTILIZER	TOTAL NH3 SCRUBBING OPERATING COST INCL REGUL.ROI FOR POWER CO.,$/YEAR	ALTERNATE WET-LIME-STONE PROCESS AIR POLLUTION CONTROL COST, $/YEAR	NET NH3 SCRUBBING COST IF DEDUCTION TAKEN FOR WET-LIME-STONE PROCESS COST, $/YEAR	NET FERTILIZER MFG COST USING (NH4)2SO4 FROM POWER PLANT, $/YEAR		NET FERTILIZER SALES REVENUE, $/YEAR	GROSS INCOME, $/YEAR		NET INCOME AFTER TAXES, $/YEAR		CASH FLOW, $/YEAR		CUMULATIVE CASH FLOW, $		ANNUAL RETURN ON INITIAL INVESTMENT, %	
						WITH DEDUCT	WITHOUT DEDUCT		WITH DEDUCT	WITHOUT DEDUCT	WITH DEDUCT	WITHOUT DEDUCT	WITH DEDUCT	WITHOUT DEDUCT	WITH DEDUCT	WITHOUT DEDUCT	WITH DEDUCT	WITHOUT DEDUCT
1																		
2																		
3																		
4	7000	235800	3140400	2261500	878900	8828500	11090000	10375200	1546700	(714800)	773350	(357400)	2206450	1075700	2206450	1075700	4.78	
5	7000	235800	3102300	2226100	876200	8825800	11051900	10375200	1549400	(676700)	774700	(338350)	2207800	1094750	4414250	2170450	4.79	
6	7000	235800	3064300	2191000	873300	8822900	11013900	10375200	1552300	(638700)	776150	(319350)	2209250	1113750	6623500	3284200	4.80	
7	7000	235800	3026200	2155600	870600	8820200	10975800	10375200	1555000	(600600)	777500	(300300)	2210600	1132800	8834100	4417000	4.80	
8	7000	235800	2988100	2120500	867600	8817700	10937700	10375200	1558000	(562500)	779000	(281250)	2212100	1151850	11046200	5568850	4.81	
9	7000	235800	2950100	2085100	865000	8814600	10899700	10375200	1560600	(524500)	780300	(262250)	221[illegible]400	1170850	13259600	6739700	4.82	
10	7000	235800	2912000	2050000	862000	8811600	10861600	10375200	1563600	(486400)	781800	(243200)	2214900	1189900	15474500	7929600	4.83	
11	5000	168200	2443900	1804000	639900	6988900	8792900	7486600	497700	(1306300)	248850	(653150)	1681950	779950	17156450	8709550	1.54	
12	5000	168200	2405900	1768900	637000	6986000	8754900	7486600	500600	(1268300)	250300	(634150)	1683400	798950	18839850	9508500	1.55	
13	5000	168200	2367800	1733500	634300	6983300	8716800	7486600	503300	(1230200)	251650	(615100)	1684750	818000	20524600	10326500	1.55	
14	5000	168200	2329700	1698300	631400	5547300	7245600	7486600	1939300	241000	969650	120500	969650	120500	21494250	10447000	5.99	0.74
15	5000	168200	2291700	1663000	628700	5544600	7207600	7486600	1942000	279000	971000	139500	971000	139500	22465250	10586500	6.00	0.86
16	3500	117900	1921100	1447600	473500	4184900	5632500	5300800	1115900	(331700)	557950	(165850)	557950	(165850)	23023200	10420650	3.45	
17	3500	117900	1883000	1412300	470700	4182100	5594400	5300800	1118700	(293600)	559350	(146800)	559350	(146800)	23582550	10273850	3.46	
18	3500	117900	1845000	1377100	467900	4179300	5556400	5300800	1121500	(255600)	560750	(127800)	560750	(127800)	24143300	10146050	3.46	
19	3500	117900	1806900	1341800	465100	4176500	5518300	5300800	1124300	(217500)	562150	(108750)	562150	(108750)	24705450	10037300	3.47	
20	3500	117900	1768900	1306600	462300	4173700	5480300	5300800	1127100	(179500)	563550	(89750)	563550	(89750)	25269000	9947550	3.48	
21	1500	50500	1265700	1061200	204500	2144400	3205600	2310400	166000	(895200)	83000	(447600)	83000	(447600)	25352000	9499950	0.51	
22	1500	50500	1227600	1025900	201700	2141600	3167500	2310400	168800	(857100)	84400	(428550)	84400	(428550)	25436400	9071400	0.52	
23	1500	50500	1189600	990700	198900	2138800	3129500	2310400	171600	(819100)	85800	(409550)	85800	(409550)	25522200	8661850	0.53	
24	1500	50500	1151500	955400	196100	2136000	3091400	2310400	174400	(781000)	87200	(390500)	87200	(390500)	25609400	8271350	0.54	
25	1500	50500	1103400	920200	183200	2123100	3043300	2310400	187300	(732900)	93650	(366450)	93650	(366450)	25703050	7904900	0.58	
26	1500	50500	1075400	884900	190500	2130400	3015300	2310400	180000	(704900)	90000	(352450)	90000	(352450)	25793050	7552450	0.56	
27	1500	50500	1037300	849700	187600	2127500	2977200	2310400	182900	(666800)	91450	(333400)	91450	(333400)	25884500	7219050	0.57	
28	1500	50500	999200	814300	184900	2124800	2939100	2310400	185600	(628700)	92800	(314350)	92800	(314350)	25977300	6904700	0.57	
29	1500	50500	961200	779200	182000	2121900	2901100	2310400	188500	(590700)	94250	(295350)	94250	(295350)	26071550	6609350	0.58	
30	1500	50500	923700	743800	179900	2119800	2863600	2310400	190600	(553200)	95300	(276600)	95300	(276600)	26166850	6332750	0.59	
31	1500	50500	885100	708700	176400	2116300	2825000	2310400	194100	(514600)	97050	(257300)	97050	(257300)	26263900	6075450	0.60	
32	1500	50500	847000	673300	173700	2113600	2786900	2310400	196800	(476500)	98400	(238250)	98400	(238250)	26362300	5837200	0.61	
33	1500	50500	808900	638200	170700	2110600	2748800	2310400	199800	(438400)	99900	(219200)	99900	(219200)	26462200	5618000	0.62	
34	1500	50500	770900	602800	168100	2108000	2710800	2310400	202400	(400400)	101200	(200200)	101200	(200200)	26563400	5417800	0.63	
35	1500	50500	732800	567700	165100	2105000	2672700	2310400	205400	(362300)	102700	(181150)	102700	(181150)	26666100	5236650	0.63	
TOTAL	114000	3838600	57226600	42858900	14367700	146549200	189408100	171219400	24670200	(18188700)	12335100	(9094350)	26666100	5236650		AVG=	2.38	

Table B-138

PROCESS B, COOPERATIVE ECONOMICS, 500 MW., NEW UNIT, 5.0% S IN COAL, 26-19-0 FERTILIZER PRODUCTION

FIXED INVESTMENT = $ 17809000
TOTAL INITIAL INVESTMENT = $ 20098000
OVERALL INTEREST RATE OF RETURN WITH DEDUCT = 17.4%
OVERALL INTEREST RATE OF RETURN WITHOUT DEDUCT = 7.9%

YEARS REQUIRED FOR PAYOUT WITH DEDUCT: 5.0
YEARS REQUIRED FOR PAYOUT WITHOUT DEDUCT: 7.6

YEARS AFTER POWER UNIT START	ANNUAL OPERATION KW-HR/ KW	TONS/YEAR FERTILIZER	TOTAL NH3 SCRUBBING OPERATING COST INCL REGUL.ROI FOR POWER CO.,$/YEAR	ALTERNATE WET-LIMESTONE PROCESS AIR POLLUTION CONTROL COST, $/YEAR	NET NH3 SCRUBBING COST IF DEDUCTION TAKEN FOR WET-LIMESTONE PROCESS COST, $/YEAR	NET FERTILIZER MFG COST USING (NH4)2SO4 FROM POWER PLANT, $/YEAR WITH DEDUCT	NET FERTILIZER MFG COST USING (NH4)2SO4 FROM POWER PLANT, $/YEAR WITHOUT DEDUCT	NET FERTILIZER SALES REVENUE, $/YEAR	GROSS INCOME, $/YEAR WITH DEDUCT	GROSS INCOME, $/YEAR WITHOUT DEDUCT	NET INCOME AFTER TAXES, $/YEAR WITH DEDUCT	NET INCOME AFTER TAXES, $/YEAR WITHOUT DEDUCT	CASH FLOW, $/YEAR WITH DEDUCT	CASH FLOW, $/YEAR WITHOUT DEDUCT	CUMULATIVE CASH FLOW, $ WITH DEDUCT	CUMULATIVE CASH FLOW, $ WITHOUT DEDUCT	ANNUAL RETURN ON INITIAL INVESTMENT, % WITH DEDUCT	ANNUAL RETURN ON INITIAL INVESTMENT, % WITHOUT DEDUCT
1	7000	328600	3244300	2506500	737800	10746900	13253400	14264500	3517600	1011100	1758800	505550	3539700	2286450	3539700	2286450	8.75	2.52
2	7000	328600	3210400	2473000	737400	10746500	13219500	14264500	3518000	1045000	1759000	522500	3539900	2303400	7079600	4589850	8.75	2.60
3	7000	328600	3176500	2439300	737200	10746300	13185600	14264500	3518200	1078900	1759100	539450	3540000	2320350	10619600	6910200	8.75	2.68
4	7000	328600	3142600	2405800	736800	10745900	13151700	14264500	3518600	1112800	1759300	556400	3540200	2337300	14159800	9247500	8.75	2.77
5	7000	328600	3108700	2372100	736600	10745700	13117800	14264500	3518800	1146700	1759400	573350	3540300	2354250	17700100	11601750	8.75	2.85
6	7000	328600	3074800	2338600	736200	10745300	13083900	14264500	3519200	1180600	1759600	590300	3540500	2371200	21240600	13972950	8.76	2.94
7	7000	328600	3040900	2304900	736000	10745100	13050000	14264500	3519400	1214500	1759700	607250	3540600	2388150	24781200	16361100	8.76	3.02
8	7000	328600	3007000	2271500	735500	10744600	13016100	14264500	3519900	1248400	1759950	624200	3540850	2405100	28322050	18766200	8.76	3.11
9	7000	328600	2973100	2238000	735100	10744200	12982200	14264500	3520300	1282300	1760150	641150	3541050	2422050	31863100	21188250	8.76	3.19
10	7000	328600	2939200	2204300	734900	10744000	12948300	14264500	3520500	1316200	1760250	658100	3541150	2439000	35404250	23627250	8.76	3.27
11	5000	234700	2429300	1903900	525400	6725800	8629700	10329100	3603300	1699400	1801650	849700	1801650	849700	37205900	24476950	8.96	4.23
12	5000	234700	2395400	1870200	525200	6725600	8595800	10329100	3603500	1733300	1801750	866650	1801750	866650	39007650	25343600	8.96	4.31
13	5000	234700	2361500	1836700	524800	6725200	8561900	10329100	3603900	1767200	1801950	883600	1801950	883600	40809600	26227200	8.97	4.40
14	5000	234700	2327600	1803000	524600	6725000	8528000	10329100	3604100	1801100	1802050	900550	1802050	900550	42611650	27127750	8.97	4.48
15	5000	234700	2293700	1769500	524200	6724600	8494100	10329100	3604500	1835000	1802250	917500	1802250	917500	44413900	28045250	8.97	4.57
16	3500	164300	1893100	1512100	381000	5013800	6525900	7317900	2304100	792000	1152050	396000	1152050	396000	45565950	28441250	5.73	1.97
17	3500	164300	1859200	1478400	380800	5013600	6492000	7317900	2304300	825900	1152150	412950	1152150	412950	46718100	28854200	5.73	2.05
18	3500	164300	1825300	1444900	380400	5013200	6458100	7317900	2304700	859800	1152350	429900	1152350	429900	47870450	29284100	5.73	2.14
19	3500	164300	1791400	1411300	380100	5012900	6424200	7317900	2305000	893700	1152500	446850	1152500	446850	49022950	29730950	5.73	2.22
20	3500	164300	1757500	1377800	379700	5012500	6390300	7317900	2305400	927600	1152700	463800	1152700	463800	50175650	30194750	5.74	2.31
21	1500	70400	1213300	1078200	135100	2570300	3648500	3201800	631500	(446700)	315750	(223350)	315750	(223350)	50491400	29971400	1.57	
22	1500	70400	1179400	1044700	134700	2569900	3614600	3201800	631900	(412800)	315950	(206400)	315950	(206400)	50807350	29765000	1.57	
23	1500	70400	1145500	1011900	134300	2569600	3580700	3201800	633000	(378900)	316500	(189450)	316500	(189450)	51123850	29575550	1.57	
24	1500	70400	1111600	977500	134100	2569300	3546800	3201800	632500	(345000)	316250	(172500)	316250	(172500)	51440100	29403050	1.57	
25	1500	70400	1077700	944000	133700	2568900	3512900	3201800	632900	(311100)	316450	(155550)	316450	(155550)	51756550	29247500	1.57	
26	1500	70400	1043800	910300	133500	2568700	3479000	3201800	633100	(277200)	316550	(138600)	316550	(138600)	52073100	29108900	1.58	
27	1500	70400	1009900	876800	133100	2568300	3445100	3201800	633500	(243300)	316750	(121650)	316750	(121650)	52389850	28987250	1.58	
28	1500	70400	976000	843100	132900	2568100	3411200	3201800	633700	(209400)	316850	(104700)	316850	(104700)	52706700	28882550	1.58	
29	1500	70400	942100	809600	132500	2567700	3377300	3201800	634100	(175500)	317050	(87750)	317050	(87750)	53023750	28794800	1.58	
30	1500	70400	908200	776200	132000	2567200	3343400	3201800	634600	(141600)	317300	(70800)	317300	(70800)	53341050	28724000	1.58	
31	1500	70400	874300	742500	131800	2567000	3309500	3201800	634800	(107700)	317400	(53850)	317400	(53850)	53658450	28670150	1.58	
32	1500	70400	840400	708800	131600	2566800	3275600	3201800	635000	(73800)	317500	(36900)	317500	(36900)	53975950	28633250	1.58	
33	1500	70400	806500	675300	131200	2566400	3241700	3201800	635400	(39900)	317700	(19950)	317700	(19950)	54293650	28613300	1.58	
34	1500	70400	772600	641800	130800	2566000	3207800	3201800	635800	(6000)	317900	(3000)	317900	(3000)	54611550	28610300	1.58	
35	1500	70400	738700	608100	130600	2565800	3173900	3201800	636000	27900	318000	13950	318000	13950	54929550	28624250	1.58	0.07
TOTAL	135000	6337000	66491500	52610600	13880900	204665900	257276500	278907000	74241100	21630500	37120550	10815250	54929550	28624250		AVG=	5.28	1.54

Table B-139

PROCESS 9, COOPERATIVE ECONOMICS, 1000 MW., NEW UNIT, 3.5% S IN COAL, 26-19-0 FERTILIZER PRODUCTION

FIXED INVESTMENT = $ 22435000
TOTAL INITIAL INVESTMENT = $ 25533400
OVERALL INTEREST RATE OF RETURN WITH DEDUCT = 18.7%
OVERALL INTEREST RATE OF RETURN WITHOUT DEDUCT = 9.0%

YEARS REQUIRED FOR PAYOUT WITH DEDUCT: 4.8
YEARS REQUIRED FOR PAYOUT WITHOUT DEDUCT: 7.3

YEARS AFTER POWER UNIT START	ANNUAL OPERATION KW-HR/KW	TONS/YEAR FERTILIZER	TOTAL NH3 SCRUBBING OPERATING COST INCL REGUL.ROI FOR POWER CO.,$/YEAR	ALTERNATE WET-LIMESTONE PROCESS AIR POLLUTION CONTROL COST, $/YEAR	NET NH3 SCRUBBING COST IF DEDUCTION TAKEN FOR WET-LIMESTONE PROCESS COST, $/YEAR	NET FERTILIZER MFG COST USING (NH4)2SO4 FROM POWER PLANT, $/YEAR		NET FERTILIZER SALES REVENUE, $/YEAR	GROSS INCOME, $/YEAR		NET INCOME AFTER TAXES, $/YEAR		CASH FLOW, $/YEAR		CUMULATIVE CASH FLOW, $		ANNUAL RETURN ON INITIAL INVESTMENT, %	
						WITH DEDUCT	WITHOUT DEDUCT		WITH DEDUCT	WITHOUT DEDUCT	WITH DEDUCT	WITHOUT DEDUCT	WITH DEDUCT	WITHOUT DEDUCT	WITH DEDUCT	WITHOUT DEDUCT	WITH DEDUCT	WITHOUT DEDUCT
1	7000	444000	4691300	3362400	1328900	14099700	17462100	18994300	4894600	1532200	2447300	766100	4690800	3009600	4690800	3009600	9.58	3.00
2	7000	444000	4640300	3317000	1323300	14094100	17411100	18994300	4900200	1583200	2450100	791600	4693600	3035100	9384400	6044700	9.60	3.10
3	7000	444000	4589400	3271900	1317500	14088300	17360200	18994300	4906000	1634100	2453000	817050	4696500	3060550	14080900	9105250	9.61	3.20
4	7000	444000	4538400	3226500	1311900	14082700	17309200	18994300	4911600	1685100	2455800	842550	4699300	3086050	18780200	12191300	9.62	3.30
5	7000	444000	4487500	3181200	1306300	14077100	17258300	18994300	4917200	1736000	2458600	868000	4702100	3111500	23482300	15302800	9.63	3.40
6	7000	444000	4436500	3135800	1300700	14071500	17207300	18994300	4922800	1787000	2461400	893500	4704900	3137000	28187200	18439800	9.64	3.50
7	7000	444000	4385600	3090700	1294900	14065700	17156400	18994300	4928600	1837900	2464300	918950	4707800	3162450	32895000	21602250	9.65	3.60
8	7000	444000	4334600	3045400	1289200	14060000	17105400	18994300	4934300	1888900	2467150	944450	4710650	3187950	37605650	24790200	9.66	3.70
9	7000	444000	4283600	3000000	1283600	14054400	17054400	18994300	4939900	1939900	2469950	969950	4713450	3213450	42319100	28003650	9.67	3.80
10	7000	444000	4232700	2954900	1277800	14048600	17003500	18994300	4945700	1990800	2472850	995400	4716350	3238900	47035450	31242550	9.68	3.90
11	5000	318000	3514300	2565100	949200	8862200	11427300	13829800	4967600	2402500	2483800	1201250	2483800	1201250	49519250	32443800	9.73	4.70
12	5000	318000	3463400	2519800	943600	8856600	11376400	13829800	4973200	2453400	2486600	1226700	2486600	1226700	52005850	33670500	9.74	4.80
13	5000	318000	3412400	2474500	937900	8850900	11325400	13829800	4978900	2504400	2489450	1252200	2489450	1252200	54495300	34922700	9.75	4.90
14	5000	318000	3361400	2429300	932100	8845100	11274400	13829800	4984700	2555400	2492350	1277700	2492350	1277700	56987650	36200400	9.76	5.00
15	5000	318000	3310500	2384000	926500	8839500	11223500	13829800	4990300	2606300	2495150	1303150	2495150	1303150	59482800	37503550	9.77	5.10
16	3500	222000	2745000	2053500	691500	6587400	8640900	9792400	3205000	1151500	1602500	575750	1602500	575750	61085300	38079300	6.28	2.25
17	3500	222000	2694100	2008400	685700	6581600	8590000	9792400	3210800	1202400	1605400	601200	1605400	601200	62690700	38680500	6.29	2.35
18	3500	222000	2643100	1963100	680000	6575900	8539000	9792400	3216500	1253400	1608250	626700	1608250	626700	64298950	39307200	6.30	2.45
19	3500	222000	2592100	1917700	674400	6570300	8488000	9792400	3222100	1304400	1611050	652200	1611050	652200	65910000	39959400	6.31	2.55
20	3500	222000	2541200	1872400	668800	6564700	8437100	9792400	3227700	1355300	1613850	677650	1613850	677650	67523850	40637050	6.32	2.65
21	1500	95200	1773400	1496500	276900	3355000	4851500	4304900	969900	(546600)	474950	(273300)	474950	(273300)	67998800	40363750	1.86	
22	1500	95200	1722500	1451200	271300	3349400	4800600	4304900	955500	(495700)	477750	(247850)	477750	(247850)	68476550	40115900	1.87	
23	1500	95200	1671500	1405800	265700	3343800	4749600	4304900	961100	(444700)	480550	(222350)	480550	(222350)	68957100	39893550	1.88	
24	1500	95200	1620500	1360700	259800	3337900	4698600	4304900	967000	(393700)	483500	(196850)	483500	(196850)	69440600	39696700	1.89	
25	1500	95200	1569600	1315400	254200	3332300	4647700	4304900	972600	(342800)	486300	(171400)	486300	(171400)	69926900	39525300	1.90	
26	1500	95200	1518600	1270000	248600	3326700	4596700	4304900	978200	(291800)	489100	(145900)	489100	(145900)	70416000	39379400	1.92	
27	1500	95200	1467700	1224700	243000	3321100	4545800	4304900	983800	(240900)	491900	(120450)	491900	(120450)	70907900	39258950	1.93	
28	1500	95200	1416700	1179500	237200	3315300	4494800	4304900	989600	(189900)	494800	(94950)	494800	(94950)	71402700	39164000	1.94	
29	1500	95200	1365700	1134200	231500	3309600	4443800	4304900	995300	(138900)	497650	(69450)	497650	(69450)	71900350	39094550	1.95	
30	1500	95200	1314800	1088800	226000	3304100	4392900	4304900	1000800	(88000)	500400	(44000)	500400	(44000)	72400750	39050550	1.96	
31	1500	95200	1263800	1043700	220100	3298200	4341900	4304900	1006700	(37000)	503350	(18500)	503350	(18500)	72904100	39032050	1.97	
32	1500	95200	1212900	998400	214500	3292600	4291000	4304900	1012300	13900	506150	6950	506150	6950	73410250	39039000	1.98	0.03
33	1500	95200	1161900	953000	208900	3287000	4240000	4304900	1017900	64900	508950	32450	508950	32450	73919200	39071450	1.99	0.13
34	1500	95200	1110900	907700	203200	3281300	4189000	4304900	1023600	115900	511800	57950	511800	57950	74431000	39129400	2.00	0.23
35	1500	95200	1060000	862500	197500	3275600	4138100	4304900	1029300	166800	514650	83400	514650	83400	74945650	39212800	2.02	0.33
TOTAL	135000	8568000	96147900	71465700	24682200	267606200	339071900	372627500	105021300	33555600	52510650	16777800	74945650	39212800		AVG=	5.88	1.86

Table B-140

PROCESS B, COOPERATIVE ECONOMICS, 1000 MW., EXISTING UNIT, 3.5% S IN COAL, 26-19-0 FERTILIZER PRODUCTION

FIXED INVESTMENT = $ 23749000
TOTAL INITIAL INVESTMENT = $ 26962000
OVERALL INTEREST RATE OF RETURN WITH DEDUCT = 15.6%
OVERALL INTEREST RATE OF RETURN WITHOUT DEDUCT = 3.3%

YEARS REQUIRED FOR PAYOUT WITH DEDUCT: 5.1
YEARS REQUIRED FOR PAYOUT WITHOUT DEDUCT: 8.6

YEARS AFTER POWER UNIT START	ANNUAL OPERATION KW-HR/KW	TONS/YEAR FERTILIZER	TOTAL NH3 SCRUBBING OPERATING COST INCL REGUL.ROI FOR POWER CO.,$/YEAR	ALTERNATE WET-LIMESTONE PROCESS AIR POLLUTION CONTROL COST, $/YEAR	NET NH3 SCRUBBING COST IF DEDUCTION TAKEN FOR WET-LIMESTONE PROCESS COST, $/YEAR	NET FERTILIZER MFG COST USING (NH4)2SO4 FROM POWER PLANT, $/YEAR WITH DEDUCT	WITHOUT DEDUCT	NET FERTILIZER SALES REVENUE, $/YEAR	GROSS INCOME, $/YEAR WITH DEDUCT	WITHOUT DEDUCT	NET INCOME AFTER TAXES, $/YEAR WITH DEDUCT	WITHOUT DEDUCT	CASH FLOW, $/YEAR WITH DEDUCT	WITHOUT DEDUCT	CUMULATIVE CASH FLOW, $ WITH DEDUCT	WITHOUT DEDUCT	ANNUAL RETURN ON INITIAL INVESTMENT, % WITH DEDUCT	WITHOUT DEDUCT
1																		
2																		
3																		
4	7000	460000	5031100	3587300	1443800	15168600	18755900	19642000	4473400	886100	2236700	443050	4611600	2817950	4611600	2817950	8.30	1.64
5	7000	460000	4971000	3533800	1437200	15162000	18695800	19642000	4480000	946200	2240000	473100	4614900	2848000	9226500	5665950	8.31	1.75
6	7000	460000	4910900	3480600	1430300	15155100	18635700	19642000	4486900	1006300	2243450	503150	4618350	2878050	13844850	8544000	8.32	1.87
7	7000	460000	4848500	3427200	1421300	15146100	18573300	19642000	4495900	1068700	2247950	534350	4622850	2909250	18467700	11453250	8.34	1.98
8	7000	460000	4790700	3373900	1416800	15141600	18515500	19642000	4500400	1126500	2250200	563250	4625100	2938150	23092800	14391400	8.35	2.09
9	7000	460000	4730600	3319900	1410700	15135500	18455400	19642000	4506500	1186600	2253250	593300	4628150	2968200	27720950	17359600	8.36	2.20
10	7000	460000	4670500	3267200	1403300	15128100	18395300	19642000	4513900	1246700	2256950	623350	4631850	2998250	32352800	20357850	8.37	2.31
11	5000	328600	3907400	2857000	1050400	11953400	14810400	14264500	2311100	(545900)	1155550	(272950)	3530450	2101950	35883250	22459800	4.29	
12	5000	328600	3847200	2803800	1043400	11946600	14750200	14264500	2318100	(485700)	1159050	(242850)	3533950	2132050	39417200	24591850	4.30	
13	5000	328600	3787100	2750300	1036800	11939800	14690100	14264500	2324700	(425600)	1162350	(212800)	3537250	2162100	42954450	26753950	4.31	
14	5000	328600	3727000	2696900	1030100	9558200	12255100	14264500	4706300	2009400	2353150	1004700	2353150	1004700	45307600	27758650	8.73	3.73
15	5000	328600	3666900	2643600	1023300	9551400	12195000	14264500	4713100	2069500	2356550	1034750	2356550	1034750	47664150	28793400	8.74	3.84
16	3500	230000	3064200	2294300	769900	7120500	9414800	10129200	3008700	714400	1504350	357200	1504350	357200	49168500	29150600	5.58	1.32
17	3500	230000	3004100	2241100	763000	7113600	9354700	10129200	3015600	774500	1507800	387250	1507800	387250	50676300	29537850	5.59	1.44
18	3500	230000	2944000	2187600	756400	7107000	9294600	10129200	3022200	834600	1511100	417300	1511100	417300	52187400	29955150	5.60	1.55
19	3500	230000	2883900	2134400	749500	7100100	9234500	10129200	3029100	894700	1514550	447350	1514550	447350	53701950	30402500	5.62	1.66
20	3500	230000	2823700	2080900	742800	7093400	9174300	10129200	3035800	954900	1517900	477450	1517900	477450	55219850	30879950	5.63	1.77
21	1500	98500	2007700	1685300	322400	3632100	5317400	4448300	816200	(869100)	408100	(434550)	408100	(434550)	55627950	30445400	1.51	
22	1500	98500	1947600	1632000	315600	3625300	5257300	4448300	823000	(809000)	411500	(404500)	411500	(404500)	56039450	30040900	1.53	
23	1500	98500	1887500	1578600	308900	3618600	5197200	4448300	829700	(748900)	414850	(374450)	414850	(374450)	56454300	29666450	1.54	
24	1500	98500	1827400	1525300	302100	3611800	5137100	4448300	836500	(688800)	418250	(344400)	418250	(344400)	56872550	29322050	1.55	
25	1500	98500	1767300	1471900	295400	3605100	5077000	4448300	843200	(628700)	421600	(314350)	421600	(314350)	57294150	29007700	1.56	
26	1500	98500	1707200	1418600	288600	3598300	5016900	4448300	850000	(568600)	425000	(284300)	425000	(284300)	57719150	28723400	1.58	
27	1500	98500	1647100	1365200	281900	3591600	4956800	4448300	856700	(508500)	428350	(254250)	428350	(254250)	58147500	28469150	1.59	
28	1500	98500	1587000	1311900	275100	3584800	4896700	4448300	863500	(448400)	431750	(224200)	431750	(224200)	58579250	28244950	1.60	
29	1500	98500	1526800	1258500	268300	3578000	4836500	4448300	870300	(388200)	435150	(194100)	435150	(194100)	59014400	28050850	1.61	
30	1500	98500	1466700	1205000	261700	3571400	4776400	4448300	876900	(328100)	438450	(164050)	438450	(164050)	59452850	27886800	1.63	
31	1500	98500	1406600	1151800	254800	3564500	4716300	4448300	883800	(268000)	441900	(134000)	441900	(134000)	59894750	27752800	1.64	
32	1500	98500	1346500	1098300	248200	3557900	4656200	4448300	890400	(207900)	445200	(103950)	445200	(103950)	60339950	27648850	1.65	
33	1500	98500	1286400	1045100	241300	3551000	4596100	4448300	897300	(147800)	448650	(73900)	448650	(73900)	60788600	27574950	1.66	
34	1500	98500	1226200	991600	234600	3544300	4535900	4448300	904000	(87600)	452000	(43800)	452000	(43800)	61240600	27531150	1.68	
35	1500	98500	1166200	938400	227800	3537500	4475900	4448300	910800	(27600)	455400	(13800)	455400	(13800)	61696000	27517350	1.69	
TOTAL	114000	7490500	91413000	68357300	23055700	250293000	318650300	326187000	75894000	7536700	37947000	3768350	61696000	27517350		AVG=	4.40	0.44

Table B-141

PROCESS C, COOPERATIVE ECONOMICS, 200 MW., EXISTING UNIT, 3.5% S IN COAL, 19-14-0 FERTILIZER PRODUCTION

FIXED INVESTMENT = $ 6709500
TOTAL INITIAL INVESTMENT = $ 7153500
OVERALL INTEREST RATE OF RETURN WITH DEDUCT = NEG
OVERALL INTEREST RATE OF RETURN WITHOUT DEDUCT = NEG

NO PAYOUT WITH DEDUCT
NO PAYOUT WITHOUT DEDUCT

YEARS AFTER POWER UNIT START	ANNUAL OPERATION KW-HR/KW	TONS/YEAR FERTILIZER	TOTAL NH3 SCRUBBING OPERATING COST INCL REGUL.ROI FOR POWER CO.,$/YEAR	ALTERNATE WET-LIMESTONE PROCESS AIR POLLUTION CONTROL COST, $/YEAR	NET NH3 SCRUBBING COST IF DEDUCTION TAKEN FOR WET-LIMESTONE PROCESS COST, $/YEAR	NET FERTILIZER MFG COST USING (NH4)2SO4 FROM POWER PLANT, $/YEAR		NET FERTILIZER SALES REVENUE, $/YEAR	GROSS INCOME, $/YEAR		NET INCOME AFTER TAXES, $/YEAR		CASH FLOW, $/YEAR		CUMULATIVE CASH FLOW, $		ANNUAL RETURN ON INITIAL INVESTMENT, %	
						WITH DEDUCT	WITHOUT DEDUCT		WITH DEDUCT	WITHOUT DEDUCT	WITH DEDUCT	WITHOUT DEDUCT	WITH DEDUCT	WITHOUT DEDUCT	WITH DEDUCT	WITHOUT DEDUCT	WITH DEDUCT	WITHOUT DEDUCT
1																		
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9	7000	56700	1540800	1097900	452900	3181800	4269700	1987300	(1196500)	(2282400)	(597250)	(1141200)	73700	(470250)	73700	(470250)		
10	7000	56700	1518800	1067700	451100	3180000	4247700	1987300	(1192700)	(2260400)	(596350)	(1130200)	74600	(459250)	148300	(929500)		
11	5000	40500	1292200	947100	345100	2625200	3572300	1428400	(1196800)	(2143900)	(598400)	(1071950)	72550	(401000)	220850	(1330500)		
12	5000	40500	1270200	927000	343200	2623300	3550300	1428400	(1194900)	(2121900)	(597450)	(1060950)	73500	(390000)	294350	(1720500)		
13	5000	40500	1248100	906800	341300	2621400	3528200	1428400	(1193000)	(2099800)	(596500)	(1049900)	74450	(378950)	368800	(2099450)		
14	5000	40500	1226100	886600	339500	2619600	3506200	1428400	(1191200)	(2077800)	(595600)	(1038900)	75350	(367950)	444150	(2467400)		
15	5000	40500	1204100	866400	337700	2617800	3484200	1428400	(1189400)	(2055800)	(594700)	(1027900)	76250	(356950)	520400	(2824350)		
16	3500	28400	1023100	762900	260200	2183800	2946700	1007300	(1176500)	(1939400)	(588250)	(969700)	82700	(298750)	603100	(3123100)		
17	3500	28400	1001100	742900	258300	2181900	2924700	1007300	(1174600)	(1917400)	(587300)	(958700)	83650	(287750)	686750	(3410850)		
18	3500	28400	979000	722600	256400	2180000	2902600	1007300	(1172700)	(1895300)	(586350)	(947650)	84600	(276700)	771350	(3687550)		
19	3500	28400	957000	702400	254600	1507300	2209700	1007300	(500000)	(1202400)	(250000)	(601200)	(250000)	(601200)	521350	(4288750)		
20	3500	28400	934900	692200	252700	1505400	2187600	1007300	(498100)	(1180300)	(249050)	(590150)	(249050)	(590150)	272300	(4878900)		
21	1500	12200	689100	553000	135100	860400	1413600	437000	(423400)	(976400)	(211700)	(488200)	(211700)	(488200)	60600	(5367100)		
22	1500	12200	666000	532900	133200	858500	1391300	437000	(421500)	(954300)	(210750)	(477150)	(210750)	(477150)	(150150)	(5844250)		
23	1500	12200	644000	512600	131400	856700	1369300	437000	(419700)	(932300)	(209850)	(466150)	(209850)	(466150)	(360000)	(6310400)		
24	1500	12200	621900	492400	129500	854800	1347200	437000	(417800)	(910200)	(208900)	(455100)	(208900)	(455100)	(568900)	(6765500)		
25	1500	12200	599900	472300	127600	852900	1325200	437000	(415900)	(888200)	(207950)	(444100)	(207950)	(444100)	(776850)	(7209600)		
26	1500	12200	577800	452100	125700	851000	1303100	437000	(414000)	(866100)	(207000)	(433050)	(207000)	(433050)	(983850)	(7642650)		
27	1500	12200	555800	431900	123900	849200	1281100	437000	(412200)	(844100)	(206100)	(422050)	(206100)	(422050)	(1189950)	(8064700)		
28	1500	12200	533700	411700	122000	847300	1259000	437000	(410300)	(822000)	(205150)	(411000)	(205150)	(411000)	(1395100)	(8475700)		
29	1500	12200	511700	391600	120100	845400	1237000	437000	(408400)	(800000)	(204200)	(400000)	(204200)	(400000)	(1599300)	(8875700)		
30	1500	12200	489600	371400	118200	843500	1214900	437000	(406500)	(777900)	(203250)	(388950)	(203250)	(388950)	(1802550)	(9264650)		
31	1500	12200	467600	351200	116400	841700	1192900	437000	(404700)	(755900)	(202350)	(377950)	(202350)	(377950)	(2004900)	(9642600)		
32	1500	12200	445500	331000	114500	839800	1170800	437000	(402800)	(733800)	(201400)	(366900)	(201400)	(366900)	(2206300)	(10009500)		
33	1500	12200	423500	310900	112600	837900	1148800	437000	(400900)	(711800)	(200450)	(355900)	(200450)	(355900)	(2406750)	(10365400)		
34	1500	12200	401400	290700	110700	836000	1126700	437000	(399000)	(689700)	(199500)	(344850)	(199500)	(344850)	(2606250)	(10710250)		
35	1500	12200	379400	270500	108900	834200	1104700	437000	(397200)	(667700)	(198600)	(333850)	(198600)	(333850)	(2804850)	(11044100)		
TOTAL	79000	640900	22201300	15478500	5722800	41735900	58215300	22708100	(19028700)	(35507200)	(9514350)	(17753600)	(2804850)	(11044100)			AVG=	

Table B-142

PROCESS C, COOPERATIVE ECONOMICS, 500 MW., NEW UNIT, 2.0% S IN COAL, 19-14-0 FERTILIZER PRODUCTION

FIXED INVESTMENT = $ 7541300
TOTAL INITIAL INVESTMENT = $ 8091300
OVERALL INTEREST RATE OF RETURN WITH DEDUCT = NEG
OVERALL INTEREST RATE OF RETURN WITHOUT DEDUCT = NEG

NO PAYOUT WITH DEDUCT
NO PAYOUT WITHOUT DEDUCT

YEARS AFTER POWER UNIT START	ANNUAL OPERA- TION KW-HR/ KW	TONS/YEAR FERTILIZER	TOTAL NH3 SCRUBBING OPERATING COST INCL REGUL.ROI FOR POWER CO.,$/YEAR	ALTERNATE WET-LIME- STONE PRO- CESS AIR POLLUTION CONTROL COST, $/YEAR	NET NH3 SCRUBBING COST IF DEDUCTION TAKEN FOR WET-LIME- STONE PRO- CESS COST, $/YEAR	NET FERTILIZER MFG COST USING (NH4)2SO4 FROM POWER PLANT, $/YEAR WITH DEDUCT	WITHOUT DEDUCT	NET FERTILIZER SALES REVENUE, $/YEAR	GROSS INCOME, $/YEAR WITH DEDUCT	WITHOUT DEDUCT	NET INCOME AFTER TAXES, $/YEAR WITH DEDUCT	WITHOUT DEDUCT	CASH FLOW, $/YEAR WITH DEDUCT	WITHOUT DEDUCT	CUMULATIVE CASH FLOW, $ WITH DEDUCT	WITHOUT DEDUCT	ANNUAL RETURN ON INITIAL INVESTMENT, % WITH DEDUCT	WITHOUT DEDUCT
1	7000	76600	2577100	1800000	777100	3893100	5693100	2667200	(1225900)	(3025900)	(612950)	(1512950)	141140	(759820)	141140	(759820)		
2	7000	76600	2544500	1772800	771700	3919700	5692500	2667200	(1252500)	(3025300)	(626250)	(1512650)	127940	(757520)	269080	(1517340)		
3	7000	76600	2511900	1749200	762700	3878700	5627800	2667200	(1211500)	(2960600)	(605750)	(1480300)	148380	(726170)	417460	(2243510)		
4	7000	76600	2479200	1718800	760400	3876400	5591200	2667200	(1209200)	(2924000)	(604600)	(1462000)	149530	(709830)	566990	(2953340)		
5	7000	76600	2446500	1690600	755900	3871900	5562500	2667200	(1204700)	(2895300)	(602350)	(1447650)	151780	(693560)	718770	(3646900)		
6	7000	76600	2413800	1663600	750200	3866400	5529800	2667200	(1199200)	(2862600)	(599600)	(1431300)	154530	(677170)	873300	(4324070)		
7	7000	76600	2381200	1635900	745300	3861300	5497200	2667200	(1194100)	(2830000)	(597050)	(1415000)	157040	(660870)	1030340	(4984940)		
8	7000	76600	2348500	1608700	739800	3855800	5464500	2667200	(1188600)	(2797300)	(594300)	(1398650)	159850	(644520)	1190190	(5629460)		
9	7000	76600	2315900	1581200	734700	3850700	5431900	2667200	(1183500)	(2764700)	(591750)	(1382350)	162380	(628220)	1352570	(6257680)		
10	7000	76600	2283200	1553600	729600	3845400	5399200	2667200	(1178200)	(2732000)	(589100)	(1366000)	165030	(611870)	1517600	(6869550)		
11	5000	54700	1949600	1379800	569800	2408100	3787900	1917900	(490200)	(1870000)	(245100)	(935000)	(245100)	(935000)	1272500	(7804550)		
12	5000	54700	1914300	1359700	554600	2402900	3755200	1917900	(485000)	(1837300)	(242500)	(918650)	(242500)	(918650)	1030000	(8723200)		
13	5000	54700	1884300	1325100	559200	2397500	3722600	1917900	(479600)	(1804700)	(239800)	(902350)	(239800)	(902350)	790200	(9625550)		
14	5000	54700	1851600	1297900	553700	2392000	3689900	1917900	(474100)	(1772000)	(237050)	(886000)	(237050)	(886000)	553150	(10511550)		
15	5000	54700	1818900	1270400	548500	2386800	3657200	1917900	(468900)	(1739300)	(234450)	(869650)	(234450)	(869650)	318700	(11381200)		
16	3500	38300	1551400	1114100	437300	1861400	2975500	1352000	(509400)	(1623500)	(254700)	(811750)	(254700)	(811750)	64000	(12192950)		
17	3500	38300	1518700	1086700	432000	1856100	2942800	1352000	(504100)	(1590800)	(252050)	(795400)	(252050)	(795400)	(188050)	(12988350)		
18	3500	38300	1486100	1059200	426900	1851000	2910200	1352000	(499000)	(1558200)	(249500)	(779100)	(249500)	(779100)	(437550)	(13767450)		
19	3500	38300	1453600	1032200	421400	1845500	2877500	1352000	(493500)	(1525500)	(246750)	(762750)	(246750)	(762750)	(684300)	(14530200)		
20	3500	38300	1420800	1005500	415300	1840400	2844900	1352000	(488400)	(1492900)	(244200)	(746450)	(244200)	(746450)	(928500)	(15276650)		
21	1500	16400	1052900	827100	225800	1042000	1869100	585500	(456500)	(1283600)	(228250)	(641800)	(228250)	(641800)	(1156750)	(15918450)		
22	1500	16400	1020300	799800	220500	1036700	1836500	585500	(451200)	(1251000)	(225600)	(625500)	(225600)	(625500)	(1382350)	(16543950)		
23	1500	16400	987600	772400	215200	1031400	1803800	585500	(445900)	(1218300)	(222950)	(609150)	(222950)	(609150)	(1605300)	(17153100)		
24	1500	16400	954900	745100	209800	1026000	1771100	585500	(440500)	(1185600)	(220250)	(592800)	(220250)	(592800)	(1825550)	(17745900)		
25	1500	16400	922300	717700	204600	1020800	1738500	585500	(435300)	(1153000)	(217650)	(576500)	(217650)	(576500)	(2043200)	(18322400)		
26	1500	16400	889600	690400	199200	1015400	1705800	585500	(429900)	(1120300)	(214950)	(560150)	(214950)	(560150)	(2258150)	(18882550)		
27	1500	16400	857000	663000	194000	1010200	1673200	585500	(424700)	(1087700)	(212350)	(543850)	(212350)	(543850)	(2470500)	(19426400)		
28	1500	16400	824300	635500	188800	1005000	1640500	585500	(419500)	(1055000)	(209750)	(527500)	(209750)	(527500)	(2680250)	(19953900)		
29	1500	16400	791700	608300	183400	999600	1607900	585500	(414100)	(1022400)	(207050)	(511200)	(207050)	(511200)	(2887300)	(20465100)		
30	1500	16400	759000	580800	178200	994400	1575200	585500	(408900)	(989700)	(204450)	(494850)	(204450)	(494850)	(3091750)	(20959950)		
31	1500	16400	726300	553600	172700	988900	1542500	585500	(403400)	(957000)	(201700)	(478500)	(201700)	(478500)	(3293450)	(21438450)		
32	1500	16400	693700	526100	167600	983800	1509900	585500	(398300)	(924400)	(199150)	(462200)	(199150)	(462200)	(3492600)	(21900650)		
33	1500	16400	661000	498900	162100	978300	1477200	585500	(392800)	(891700)	(196400)	(445850)	(196400)	(445850)	(3689000)	(22346500)		
34	1500	16400	628400	471400	157000	973200	1444600	585500	(387700)	(859100)	(193850)	(429550)	(193850)	(429550)	(3882850)	(22776050)		
35	1500	16400	595700	444200	151500	967700	1411900	585500	(382200)	(826400)	(191100)	(413200)	(191100)	(413200)	(4073950)	(23149250)		
TOTAL	135000	1477000	53519100	38231600	15287500	75034000	113264600	51803500	(23230500)	(61461100)	(11615250)	(30730550)	(4073950)	(23149250)			AVG=	

Table B-143

PROCESS C, COOPERATIVE ECONOMICS, 500 MW., NEW UNIT, 3.5% S IN COAL, 19-14-0 FERTILIZER PRODUCTION

FIXED INVESTMENT = $ 10420800
TOTAL INITIAL INVESTMENT = $ 11270900
OVERALL INTEREST RATE OF RETURN WITH DEDUCT = NEG
OVERALL INTEREST RATE OF RETURN WITHOUT DEDUCT = NEG

NO PAYOUT WITH DEDUCT
NO PAYOUT WITHOUT DEDUCT

YEARS AFTER POWER UNIT START	ANNUAL OPERA-TION KW-HR/KW	TONS/YEAR FERTILIZER	TOTAL SO2 SCRUBBING OPERATING COST INCL. STOR. AND FOR POWER CO.,$/YEAR	ALTERNATE WET-LIME-STONE PRO-CESS AIR POLLUTION CONTROL COST, $/YEAR	NET SO2 SCRUBBING COST IF DEDUCTION TAKEN FOR WET-LIME-STONE PRO-CESS COST, $/YEAR	NET FERTILIZER MFG COST USING (NH4)2SO4 FROM POWER PLANT, $/YEAR		NET FERTILIZER SALES REVENUE, $/YEAR	GROSS INCOME, $/YEAR		NET INCOME AFTER TAXES, $/YEAR		CASH FLOW, $/YEAR		CUMULATIVE CASH FLOW, $		ANNUAL RETURN ON INITIAL INVESTMENT, %	
						WITH DEDUCT	WITHOUT DEDUCT		WITH DEDUCT	WITHOUT DEDUCT	WITH DEDUCT	WITHOUT DEDUCT	WITH DEDUCT	WITHOUT DEDUCT	WITH DEDUCT	WITHOUT DEDUCT	WITH DEDUCT	WITHOUT DEDUCT
1	7000	134000	3190000	2150200	1039800	5708700	7858900	4596200	(1112500)	(3262700)	(556250)	(1631350)	485830	(589270)	485830	(589270)		
2	7000	134000	3154800	2119600	1035200	5704100	7823700	4596200	(1107900)	(3227500)	(553950)	(1613750)	488130	(571670)	973960	(1160940)		
3	7000	134000	3119700	2089200	1030500	5699400	7788600	4596200	(1103200)	(3192400)	(551600)	(1596200)	490480	(554120)	1464440	(1715060)		
4	7000	134000	3084500	2058700	1025800	5694700	7753400	4596200	(1098500)	(3157200)	(549250)	(1578600)	492830	(536520)	1957270	(2251580)		
5	7000	134000	3049400	2028100	1021300	5690200	7718300	4596200	(1094000)	(3122100)	(547000)	(1561050)	495080	(518970)	2452350	(2770550)		
6	7000	134000	3014200	1997500	1016700	5685600	7683100	4596200	(1089400)	(3086900)	(544700)	(1543450)	497380	(501370)	2949730	(3271920)		
7	7000	134000	2979100	1967100	1012000	5680900	7648000	4596200	(1084700)	(3051800)	(542350)	(1525900)	499730	(483820)	3449460	(3755740)		
8	7000	134000	2943900	1936600	1007300	5676200	7612800	4596200	(1080000)	(3016600)	(540000)	(1508300)	502080	(466220)	3951540	(4221960)		
9	7000	134000	2908800	1906000	1002800	5671700	7577700	4596200	(1075500)	(2981500)	(537750)	(1490750)	504330	(448670)	4455870	(4670630)		
10	7000	134000	2873600	1875600	998000	5666900	7542500	4596200	(1070700)	(2946300)	(535350)	(1473150)	506730	(431070)	4962600	(5101700)		
11	5000	95700	2396100	1640100	756000	3552500	5192600	3314100	(238400)	(1878500)	(119200)	(939250)	(119200)	(939250)	4843400	(6040950)		
12	5000	95700	2360900	1610000	750900	3547400	5157400	3314100	(233300)	(1843300)	(116650)	(921650)	(116650)	(921650)	4726750	(6962600)		
13	5000	95700	2325800	1579400	746400	3542900	5122300	3314100	(228800)	(1808200)	(114400)	(904100)	(114400)	(904100)	4612350	(7866700)		
14	5000	95700	2290600	1549000	741600	3538100	5087100	3314100	(224000)	(1773000)	(112000)	(886500)	(112000)	(886500)	4500350	(8753200)		
15	5000	95700	2255500	1518400	737100	3533600	5052000	3314100	(219500)	(1737900)	(109750)	(868950)	(109750)	(868950)	4390600	(9622150)		
16	3500	67000	1878800	1311600	567200	2708800	4020400	2340300	(368500)	(1680100)	(184250)	(840050)	(184250)	(840050)	4206350	(10462200)		
17	3500	67000	1843700	1281200	562500	2704100	3985300	2340300	(363800)	(1645000)	(181900)	(822500)	(181900)	(822500)	4024450	(11284700)		
18	3500	67000	1808500	1250600	557900	2699500	3950100	2340300	(359200)	(1609800)	(179600)	(804900)	(179600)	(804900)	3844850	(12089600)		
19	3500	67000	1773400	1220100	553300	2694900	3915000	2340300	(354600)	(1574700)	(177300)	(787350)	(177300)	(787350)	3667550	(12876950)		
20	3500	67000	1738200	1189700	548500	2690100	3879800	2340300	(349800)	(1539500)	(174900)	(769750)	(174900)	(769750)	3492650	(13646700)		
21	1500	28700	1223300	952200	271100	1467100	2419300	1017700	(449400)	(1401600)	(224700)	(700800)	(224700)	(700800)	3267950	(14347500)		
22	1500	28700	1188200	921600	266600	1462600	2384200	1017700	(444900)	(1366500)	(222450)	(683250)	(222450)	(683250)	3045500	(15030750)		
23	1500	28700	1153000	891100	261900	1457900	2349000	1017700	(440200)	(1331300)	(220100)	(665650)	(220100)	(665650)	2825400	(15696400)		
24	1500	28700	1117900	860700	257200	1453200	2313900	1017700	(435500)	(1296200)	(217750)	(648100)	(217750)	(648100)	2607650	(16344500)		
25	1500	28700	1082700	830100	252600	1448600	2278700	1017700	(430900)	(1261000)	(215450)	(630500)	(215450)	(630500)	2392200	(16975000)		
26	1500	28700	1047600	799500	248100	1444100	2243600	1017700	(426400)	(1225900)	(213200)	(612950)	(213200)	(612950)	2179000	(17587950)		
27	1500	28700	1012400	769200	243200	1439200	2208400	1017700	(421500)	(1190700)	(210750)	(595350)	(210750)	(595350)	1968250	(18183300)		
28	1500	28700	977300	738400	238900	1434900	2173300	1017700	(417200)	(1155600)	(208600)	(577800)	(208600)	(577800)	1759650	(18761100)		
29	1500	28700	942100	708100	234000	1430000	2138100	1017700	(412300)	(1120400)	(206150)	(560200)	(206150)	(560200)	1553500	(19321300)		
30	1500	28700	907000	677400	229600	1425600	2103000	1017700	(407900)	(1085300)	(203950)	(542650)	(203950)	(542650)	1349550	(19863950)		
31	1500	28700	871800	647100	224700	1420700	2067800	1017700	(403000)	(1050100)	(201500)	(525050)	(201500)	(525050)	1148050	(20389000)		
32	1500	28700	836700	616500	220200	1416200	2032700	1017700	(398500)	(1015000)	(199250)	(507500)	(199250)	(507500)	948800	(20896500)		
33	1500	28700	801500	585900	215600	1411600	1997500	1017700	(393900)	(979800)	(196950)	(489900)	(196950)	(489900)	751850	(21386400)		
34	1500	28700	766400	555600	210800	1406800	1962400	1017700	(389100)	(944700)	(194550)	(472350)	(194550)	(472350)	557300	(21858750)		
35	1500	28700	731200	525000	206200	1402200	1927200	1017700	(384500)	(909500)	(192250)	(454750)	(192250)	(454750)	365050	(22313500)		
TOTAL	135000	2584000	65648600	45357100	20291500	109612000	154969100	89499500	(20111500)	(65468600)	(10055750)	(32734300)	365050	(22313500)			AVG=	

Table B-144

PROCESS C, COOPERATIVE ECONOMICS, 500 MW., EXISTING UNIT, 3.5% S IN COAL, 19-14-0 FERTILIZER PRODUCTION

FIXED INVESTMENT = $ 11060600
TOTAL INITIAL INVESTMENT = $ 11965500
OVERALL INTEREST RATE OF RETURN WITH DEDUCT = NEG
OVERALL INTEREST RATE OF RETURN WITHOUT DEDUCT = NEG

NO PAYOUT WITH DEDUCT
NO PAYOUT WITHOUT DEDUCT

YEARS AFTER POWER UNIT START	ANNUAL OPERATION KW-HR/KW	TONS/YEAR FERTILIZER	TOTAL NH3 SCRUBBING OPERATING COST INCL REGUL.ROI FOR POWER CO.,$/YEAR	ALTERNATE WET-LIMESTONE PROCESS AIR POLLUTION CONTROL COST, $/YEAR	NET NH3 SCRUBBING COST IF DEDUCTION TAKEN FOR WET-LIMESTONE PROCESS COST, $/YEAR	NET FERTILIZER MFG COST USING (NH4)2SO4 FROM POWER PLANT, $/YEAR		NET FERTILIZER SALES REVENUE, $/YEAR	GROSS INCOME, $/YEAR		NET INCOME AFTER TAXES, $/YEAR		CASH FLOW, $/YEAR		CUMULATIVE CASH FLOW, $		ANNUAL RETURN ON INITIAL INVESTMENT, %	
						WITH DEDUCT	WITHOUT DEDUCT		WITH DEDUCT	WITHOUT DEDUCT	WITH DEDUCT	WITHOUT DEDUCT	WITH DEDUCT	WITHOUT DEDUCT	WITH DEDUCT	WITHOUT DEDUCT	WITH DEDUCT	WITHOUT DEDUCT
1																		
2																		
3																		
4	7000	137000	3357800	2261500	1096300	6143900	8405400	4695000	(1448900)	(3710400)	(724450)	(1855200)	381610	(749140)	381610	(749140)		
5	7000	137000	3317200	2226100	1091100	6138700	8364800	4695000	(1443700)	(3669800)	(721950)	(1834900)	384210	(729840)	765820	(1477980)		
6	7000	137000	3276600	2191000	1085600	6133200	8324200	4695000	(1438200)	(3629200)	(719100)	(1814600)	386960	(708540)	1152780	(2186520)		
7	7000	137000	3236100	2155600	1080500	6128100	8283700	4695000	(1433100)	(3588700)	(716550)	(1794350)	389510	(688290)	1542290	(2874810)		
8	7000	137000	3195500	2120500	1075000	6122600	8243100	4695000	(1427600)	(3548100)	(713800)	(1774050)	392260	(667990)	1934550	(3542800)		
9	7000	137000	3154900	2085100	1069800	6117400	8202500	4695000	(1422400)	(3507500)	(711200)	(1753750)	394860	(647690)	2329410	(4190490)		
10	7000	137000	3114400	2050000	1064400	6112000	8162000	4695000	(1417000)	(3467000)	(708500)	(1733500)	397560	(627440)	2726970	(4817930)		
11	5000	97900	2614800	1804000	810800	4949900	6753900	3388300	(1561600)	(3365600)	(780800)	(1682800)	325260	(576740)	3052230	(5394670)		
12	5000	97900	2574300	1768900	805400	4944500	6713400	3388300	(1556200)	(3325100)	(778100)	(1662550)	327960	(556490)	3380190	(5951160)		
13	5000	97900	2533700	1733500	800200	4939300	6672800	3388300	(1551000)	(3284500)	(775500)	(1642250)	330560	(536190)	3710750	(6487350)		
14	5000	97900	2493200	1698300	794900	3827900	5526200	3388300	(439600)	(2137900)	(219800)	(1068950)	(219800)	(1068950)	3490950	(7556300)		
15	5000	97900	2452600	1663000	789600	3822600	5485600	3388300	(434300)	(2097300)	(217150)	(1048650)	(217150)	(1048650)	3273800	(8604950)		
16	3500	68500	2057400	1447600	609800	2930300	4377900	2391300	(539000)	(1986600)	(269500)	(993300)	(269500)	(993300)	3004300	(9598250)		
17	3500	68500	2016900	1412300	604600	2925100	4337400	2391300	(533800)	(1946100)	(266900)	(973050)	(266900)	(973050)	2737400	(10571300)		
18	3500	68500	1976300	1377100	599200	2919700	4296800	2391300	(528400)	(1905500)	(264200)	(952750)	(264200)	(952750)	2473200	(11524050)		
19	3500	68500	1935700	1341800	593900	2914400	4256200	2391300	(523100)	(1864900)	(261550)	(932450)	(261550)	(932450)	2211650	(12456500)		
20	3500	68500	1895200	1306600	588600	2909100	4215700	2391300	(517800)	(1824400)	(258900)	(912200)	(258900)	(912200)	1952750	(13368700)		
21	1500	29600	1356500	1061200	295300	1586000	2647200	1042200	(543800)	(1605000)	(271900)	(802500)	(271900)	(802500)	1680850	(14171200)		
22	1500	29600	1315900	1025900	290000	1580700	2606600	1042200	(538500)	(1564400)	(269250)	(782200)	(269250)	(782200)	1411600	(14953400)		
23	1500	29600	1275400	990700	284700	1575400	2566100	1042200	(533200)	(1523900)	(266600)	(761950)	(266600)	(761950)	1145000	(15715350)		
24	1500	29600	1234900	955400	279500	1570200	2525600	1042200	(528000)	(1483400)	(264000)	(741700)	(264000)	(741700)	881000	(16457050)		
25	1500	29600	1194300	920200	274100	1564800	2485000	1042200	(522600)	(1442800)	(261300)	(721400)	(261300)	(721400)	619700	(17178450)		
26	1500	29600	1153700	884900	268800	1559500	2444400	1042200	(517300)	(1402200)	(258650)	(701100)	(258650)	(701100)	361050	(17879550)		
27	1500	29600	1113200	849700	263500	1554200	2403900	1042200	(512000)	(1361700)	(256000)	(680850)	(256000)	(680850)	105050	(18560400)		
28	1500	29600	1072600	814300	258300	1549000	2363300	1042200	(506800)	(1321100)	(253600)	(660550)	(253600)	(660550)	(148350)	(19220950)		
29	1500	29600	1032100	779200	252900	1543600	2322800	1042200	(501400)	(1280600)	(250700)	(640300)	(250700)	(640300)	(399050)	(19861250)		
30	1500	29600	991500	743800	247700	1538600	2282200	1042200	(496200)	(1240000)	(248100)	(620000)	(248100)	(620000)	(647150)	(20481250)		
31	1500	29600	951000	708700	242300	1533000	2241700	1042200	(490800)	(1199500)	(245400)	(599750)	(245400)	(599750)	(892550)	(21081000)		
32	1500	29600	910400	673300	237100	1527800	2201100	1042200	(485600)	(1158900)	(242900)	(579450)	(242800)	(579450)	(1135350)	(21660450)		
33	1500	29600	869800	638200	231600	1522300	2160500	1042200	(480100)	(1118300)	(240050)	(559150)	(240050)	(559150)	(1375400)	(22219600)		
34	1500	29600	829300	602900	226500	1517200	2120000	1042200	(475000)	(1077800)	(237500)	(538900)	(237500)	(538900)	(1612900)	(22758500)		
35	1500	29600	788700	567700	221000	1511700	2079400	1042200	(469500)	(1037200)	(234750)	(518600)	(234750)	(518600)	(1847650)	(23277100)		
TOTAL	114000	2232000	61291900	42858900	18433000	103712500	146071400	77396000	(25816500)	(68675400)	(12908250)	(34337700)	(1847650)	(23277100)			AVG=	

Table B-145

PROCESS C, COOPERATIVE ECONOMICS, 500 MW., NEW UNIT, 5.0% S IN COAL, 19-14-0 FERTILIZER PRODUCTION

FIXED INVESTMENT = $ 11235900
TOTAL INITIAL INVESTMENT = $ 12305900
OVERALL INTEREST RATE OF RETURN WITH DEDUCT = NEG
OVERALL INTEREST RATE OF RETURN WITHOUT DEDUCT = NEG

NO PAYOUT WITH DEDUCT
NO PAYOUT WITHOUT DEDUCT

YEARS AFTER POWER UNIT START	ANNUAL OPERA-TION KW-HR/ KW	TONS/YEAR FERTILIZER	TOTAL NH3 SCRUBBING OPERATING COST INCL REGUL.ROI FOR POWER CO.,$/YEAR	ALTERNATE WET-LIME-STONE PRO-CESS AIR POLLUTION CONTROL COST, $/YEAR	NET NH3 SCRUBBING COST IF DEDUCTION TAKEN FOR WET-LIME-STONE PRO-CESS COST, $/YEAR	NET FERTILIZER MFG COST USING (NH4)2SO4 FROM POWER PLANT, $/YEAR		NET FERTILIZER SALES REVENUE, $/YEAR	GROSS INCOME, $/YEAR		NET INCOME AFTER TAXES, $/YEAR		CASH FLOW, $/YEAR		CUMULATIVE CASH FLOW, $		ANNUAL RETURN ON INITIAL INVESTMENT, %	
						WITH DEDUCT	WITHOUT DEDUCT		WITH DEDUCT	WITHOUT DEDUCT	WITH DEDUCT	WITHOUT DEDUCT	WITH DEDUCT	WITHOUT DEDUCT	WITH DEDUCT	WITHOUT DEDUCT	WITH DEDUCT	WITHOUT DEDUCT
1	7000	191400	3771700	2506500	1265200	7002300	9508800	6482700	(519600)	(3026100)	(259800)	(1513050)	863790	(389460)	863790	(389460)		
2	7000	191400	3734300	2473000	1261300	6998400	9471400	6482700	(515700)	(2988700)	(257850)	(1494350)	865740	(370760)	1729530	(760220)		
3	7000	191400	3696900	2439300	1257600	6994700	9434000	6482700	(512000)	(2951300)	(256000)	(1475650)	867590	(352060)	2597120	(1112280)		
4	7000	191400	3659400	2405800	1253600	6990700	9396500	6482700	(508000)	(2913800)	(254000)	(1456900)	869590	(333310)	3466710	(1445590)		
5	7000	191400	3621900	2372100	1249800	6986900	9359000	6482700	(504200)	(2876300)	(252100)	(1438150)	871490	(314560)	4338200	(1760150)		
6	7000	191400	3584500	2338600	1245900	6983000	9321600	6482700	(500300)	(2838900)	(250150)	(1419450)	873440	(295860)	5211640	(2056010)		
7	7000	191400	3547100	2304900	1242200	6979300	9284200	6482700	(496600)	(2801500)	(248300)	(1400750)	875290	(277160)	6086930	(2333170)		
8	7000	191400	3509700	2271500	1238200	6975300	9246800	6482700	(492600)	(2764100)	(246300)	(1382050)	877290	(258460)	6964220	(2591630)		
9	7000	191400	3472200	2238000	1234200	6971300	9209300	6482700	(488600)	(2726600)	(244300)	(1363300)	879290	(239710)	7843510	(2831340)		
10	7000	191400	3434800	2204300	1230500	6967600	9171900	6482700	(484900)	(2689200)	(242450)	(1344600)	881140	(221010)	8724650	(3052350)		
11	5000	136700	2818400	1903900	914500	4439300	6343200	4684700	245400	(1658500)	122700	(829250)	122700	(829250)	8847350	(3881600)	1.00	
12	5000	136700	2780900	1870200	910700	4435500	6305700	4684700	249200	(1621000)	124600	(810500)	124600	(810500)	8971950	(4692100)	1.01	
13	5000	136700	2743500	1836700	906800	4431600	6268300	4684700	253100	(1583600)	126550	(791800)	126550	(791800)	9098500	(5483900)	1.03	
14	5000	136700	2706000	1803000	903000	4427800	6230900	4684700	256900	(1546100)	128450	(773050)	128450	(773050)	9226950	(6256950)	1.04	
15	5000	136700	2668600	1769500	899100	4423900	6193400	4684700	260800	(1508700)	130400	(754350)	130400	(754350)	9357350	(7011300)	1.06	
16	3500	95700	2186700	1512100	674600	3349700	4861800	3314100	(35600)	(1547700)	(17800)	(773850)	(17800)	(773850)	9339550	(7785150)		
17	3500	95700	2149200	1478400	670800	3345900	4824300	3314100	(31800)	(1510200)	(15900)	(755100)	(15900)	(755100)	9323650	(8540250)		
18	3500	95700	2111800	1444900	666900	3342000	4786900	3314100	(27900)	(1472800)	(13950)	(736400)	(13950)	(736400)	9309700	(9276650)		
19	3500	95700	2074300	1411300	663000	3338100	4749400	3314100	(24000)	(1435300)	(12000)	(717650)	(12000)	(717650)	9297700	(9994300)		
20	3500	95700	2036900	1377800	659100	3334200	4712000	3314100	(20100)	(1397900)	(10050)	(698950)	(10050)	(698950)	9287650	(10693250)		
21	1500	41000	1380600	1078200	302400	1759100	2837300	1446100	(313000)	(1391200)	(156500)	(695600)	(156500)	(695600)	9131150	(11388850)		
22	1500	41000	1343100	1044700	298400	1755100	2799800	1446100	(309000)	(1353700)	(154500)	(676850)	(154500)	(676850)	8976650	(12065700)		
23	1500	41000	1305700	1011900	293800	1750500	2762400	1446100	(304400)	(1316300)	(152200)	(658150)	(152200)	(658150)	8824450	(12723850)		
24	1500	41000	1268200	977500	290700	1747400	2724900	1446100	(301300)	(1278800)	(150650)	(639400)	(150650)	(639400)	8673800	(13363250)		
25	1500	41000	1230800	944000	286800	1743500	2687500	1446100	(297400)	(1241400)	(148700)	(620700)	(148700)	(620700)	8525100	(13983950)		
26	1500	41000	1193400	910300	283100	1739800	2650100	1446100	(293700)	(1204000)	(146850)	(602000)	(146850)	(602000)	8378250	(14585950)		
27	1500	41000	1155900	876800	279100	1735800	2612600	1446100	(289700)	(1166500)	(144850)	(583250)	(144850)	(583250)	8233400	(15169200)		
28	1500	41000	1118500	843100	275400	1732100	2575200	1446100	(286000)	(1129100)	(143000)	(564550)	(143000)	(564550)	8090400	(15733750)		
29	1500	41000	1081000	809600	271400	1728100	2537700	1446100	(282000)	(1091600)	(141000)	(545800)	(141000)	(545800)	7949400	(16279550)		
30	1500	41000	1043600	776200	267400	1724100	2500300	1446100	(278000)	(1054200)	(139000)	(527100)	(139000)	(527100)	7810400	(16806650)		
31	1500	41000	1006100	742500	263600	1720300	2462800	1446100	(274200)	(1016700)	(137100)	(508350)	(137100)	(508350)	7673300	(17315000)		
32	1500	41000	968700	708800	259900	1716600	2425400	1446100	(270500)	(979300)	(135250)	(489650)	(135250)	(489650)	7538050	(17804650)		
33	1500	41000	931300	675300	256000	1712700	2388000	1446100	(266600)	(941900)	(133300)	(470950)	(133300)	(470950)	7404750	(18275600)		
34	1500	41000	893800	641900	252000	1708700	2350500	1446100	(262600)	(904400)	(131300)	(452200)	(131300)	(452200)	7273450	(18727800)		
35	1500	41000	856400	608100	248300	1705000	2313100	1446100	(258900)	(867000)	(129450)	(433500)	(129450)	(433500)	7144000	(19161300)		
TOTAL	135000	3691000	77085900	52610600	24475300	134696300	187306900	126512500	(8183800)	(60794400)	(4091900)	(30397200)	7144000	(19161300)		AVG=		

Table B-146

PROCESS C, COOPERATIVE ECONOMICS, 1000 MW., NEW UNIT, 3.5% S IN COAL, 19-14-0 FERTILIZER PRODUCTION

FIXED INVESTMENT = $ 15326300
TOTAL INITIAL INVESTMENT = $ 16731300
OVERALL INTEREST RATE OF RETURN WITH DEDUCT = NEG
OVERALL INTEREST RATE OF RETURN WITHOUT DEDUCT = NEG

NO PAYOUT WITH DEDUCT
NO PAYOUT WITHOUT DEDUCT

YEARS AFTER POWER UNIT START	ANNUAL OPERA- TION KW-HR/ KW	TONS/YEAR FERTILIZER	TOTAL NH3 SCRUBBING OPERATING COST INCL REGUL.ROI FOR POWER CO.,$/YEAR	ALTERNATE WET-LIME- STONE PRO- CESS AIR POLLUTION CONTROL COST, $/YEAR	NET NH3 SCRUBBING COST IF DEDUCTION TAKEN FOR WET-LIME- STONE PRO- CESS COST, $/YEAR	NET FERTILIZER MFG COST USING (NH4)2SO4 FROM POWER PLANT, $/YEAR		NET FERTILIZER SALES REVENUE, $/YEAR	GROSS INCOME, $/YEAR		NET INCOME AFTER TAXES, $/YEAR		CASH FLOW, $/YEAR		CUMULATIVE CASH FLOW, $		ANNUAL RETURN ON INITIAL INVESTMENT, %	
						WITH DEDUCT	WITHOUT DEDUCT		WITH DEDUCT	WITHOUT DEDUCT	WITH DEDUCT	WITHOUT DEDUCT	WITH DEDUCT	WITHOUT DEDUCT	WITH DEDUCT	WITHOUT DEDUCT	WITH DEDUCT	WITHOUT DEDUCT
1	7000	259500	5315400	3362400	1953000	9331000	12693400	8677700	(653300)	(4015700)	(326650)	(2007850)	1205980	(475220)	1205980	(475220)		
2	7000	259500	5260100	3317000	1943100	9321100	12638100	8677700	(643400)	(3960400)	(321700)	(1980200)	1210930	(447570)	2416910	(922790)		
3	7000	259500	5204700	3271900	1932800	9310800	12582700	8677700	(633100)	(3905000)	(316550)	(1952500)	1216080	(419870)	3632990	(1342660)		
4	7000	259500	5149400	3226500	1922900	9300900	12527600	8677700	(623200)	(3849700)	(311600)	(1924850)	1221030	(392220)	4854020	(1734880)		
5	7000	259500	5094100	3181200	1912900	9290900	12472100	8677700	(613200)	(3794600)	(306600)	(1897300)	1226030	(364570)	6080050	(2099450)		
6	7000	259500	5038800	3135800	1903000	9281000	12416800	8677700	(603300)	(3739100)	(301650)	(1869550)	1230980	(336920)	7311030	(2436370)		
7	7000	259500	4983400	3090700	1892700	9270700	12361400	8677700	(593000)	(3683700)	(296500)	(1841850)	1236130	(309220)	8547160	(2745590)		
8	7000	259500	4928100	3045400	1882700	9260700	12306100	8677700	(583000)	(3628400)	(291500)	(1814200)	1241130	(281570)	9788290	(3027160)		
9	7000	259500	4872800	3000000	1872800	9250800	12250800	8677700	(573100)	(3573100)	(286550)	(1786550)	1246080	(253920)	11034370	(3281080)		
10	7000	259500	4817600	2954900	1862500	9240500	12195400	8677700	(562800)	(3517700)	(281400)	(1758850)	1251230	(226220)	12285600	(3507300)		
11	5000	185400	3975700	2565100	1410600	5876700	8441800	6286900	410200	(2154900)	205100	(1077450)	205100	(1077450)	12490700	(4584750)	1.25	
12	5000	185400	3920400	2519800	1400600	5866700	8386500	6286900	420200	(2099600)	210100	(1049800)	210100	(1049800)	12700800	(5634550)	1.26	
13	5000	185400	3865000	2474500	1390500	5856600	8331100	6286900	430300	(2044200)	215150	(1022100)	215150	(1022100)	12915950	(6656650)	1.29	
14	5000	185400	3809700	2429300	1380400	5846500	8275800	6286900	440400	(1988900)	220200	(994450)	220200	(994450)	13136150	(7651100)	1.32	
15	5000	185400	3754400	2384000	1370400	5836500	8220500	6286900	450400	(1933600)	225200	(966800)	225200	(966800)	13361350	(8617900)	1.35	
16	3500	129800	3094900	2053500	1041400	4432000	6485500	4456000	24000	(2029500)	12000	(1014750)	12000	(1014750)	13373350	(9632650)	0.07	
17	3500	129800	3039500	2008600	1031100	4421700	6430100	4456000	34300	(1974100)	17150	(987050)	17150	(987050)	13390500	(10619700)	0.10	
18	3500	129800	2984200	1963100	1021100	4411700	6374800	4456000	44300	(1918800)	22150	(959400)	22150	(959400)	13412650	(11579100)	0.13	
19	3500	129800	2928900	1917700	1011200	4401800	6319500	4456000	54200	(1863500)	27100	(931750)	27100	(931750)	13439750	(12510850)	0.16	
20	3500	129800	2873500	1872400	1001100	4391700	6264100	4456000	64300	(1808100)	32150	(904050)	32150	(904050)	13471900	(13414900)	0.19	
21	1500	55600	1975800	1496500	479300	2330300	3826800	1949300	(381000)	(1877500)	(190500)	(938750)	(190500)	(938750)	13281400	(14353650)		
22	1500	55600	1920500	1451200	469300	2320300	3771500	1949300	(371000)	(1822200)	(185500)	(911100)	(185500)	(911100)	13095900	(15264750)		
23	1500	55600	1865200	1405800	459600	2310400	3716200	1949300	(361100)	(1766900)	(180550)	(883450)	(180550)	(883450)	12915350	(16148200)		
24	1500	55600	1809900	1360700	449200	2300200	3660900	1949300	(350900)	(1711600)	(175450)	(855800)	(175450)	(855800)	12739900	(17004000)		
25	1500	55600	1754500	1315600	439100	2290100	3605500	1949300	(340800)	(1656200)	(170400)	(828100)	(170400)	(828100)	12569500	(17832100)		
26	1500	55600	1699200	1270000	429200	2280200	3550200	1949300	(330900)	(1600900)	(165450)	(800450)	(165450)	(800450)	12404050	(18632550)		
27	1500	55600	1643900	1224700	419200	2270200	3494900	1949300	(320900)	(1545600)	(160450)	(772800)	(160450)	(772800)	12243600	(19405350)		
28	1500	55600	1588500	1179500	409000	2260000	3439500	1949300	(310700)	(1490200)	(155350)	(745100)	(155350)	(745100)	12088250	(20150450)		
29	1500	55600	1533200	1134200	399000	2250000	3384200	1949300	(300700)	(1434900)	(150350)	(717450)	(150350)	(717450)	11937900	(20867900)		
30	1500	55600	1477900	1088800	389100	2240100	3328900	1949300	(290800)	(1379600)	(145400)	(689800)	(145400)	(689800)	11792500	(21557700)		
31	1500	55600	1422600	1043700	378900	2229900	3273600	1949300	(280600)	(1324300)	(140300)	(662150)	(140300)	(662150)	11652200	(22219850)		
32	1500	55600	1367200	998600	368800	2219800	3218200	1949300	(270500)	(1268900)	(135250)	(634450)	(135250)	(634450)	11516950	(22854300)		
33	1500	55600	1311900	953000	358900	2209900	3162900	1949300	(260600)	(1213600)	(130300)	(606800)	(130300)	(606800)	11386650	(23461100)		
34	1500	55600	1256600	907700	348900	2199900	3107600	1949300	(250600)	(1158300)	(125300)	(579150)	(125300)	(579150)	11261350	(24040250)		
35	1500	55600	1201200	862500	338700	2189700	3052200	1949300	(240600)	(1102900)	(120200)	(551450)	(120200)	(551450)	11141150	(24591700)		
TOTAL	135000	5005000	108738500	71465700	37272800	178101300	249567000	169731000	(8370300)	(79836000)	(4185150)	(39918000)	11141150	(24591700)		AVG=		

Table B-147

PROCESS C, COOPERATIVE ECONOMICS, 1000 MW., EXISTING UNIT, 3.5% S IN COAL, 19-14-0 FERTILIZER PRODUCTION

FIXED INVESTMENT = $ 16728400
TOTAL INITIAL INVESTMENT = $ 18263400
OVERALL INTEREST RATE OF RETURN WITH DEDUCT = NEG
OVERALL INTEREST RATE OF RETURN WITHOUT DEDUCT = NEG

NO PAYOUT WITH DEDUCT
NO PAYOUT WITHOUT DEDUCT

YEARS AFTER POWER UNIT START	ANNUAL OPERATION KW-HR/KW	TONS/YEAR FERTILIZER	TOTAL NH3 SCRUBBING OPERATING COST INCL REGUL.ROI FOR POWER CO., $/YEAR	ALTERNATE WET-LIMESTONE PROCESS AIR POLLUTION CONTROL COST, $/YEAR	NET NH3 SCRUBBING COST IF DEDUCTION TAKEN FOR WET-LIMESTONE PROCESS COST, $/YEAR	NET FERTILIZER MFG COST USING (NH4)2SO4 FROM POWER PLANT, $/YEAR		NET FERTILIZER SALES REVENUE $/YEAR	GROSS INCOME, $/YEAR		NET INCOME AFTER TAXES, $/YEAR		CASH FLOW, $/YEAR		CUMULATIVE CASH FLOW, $		ANNUAL RETURN ON INITIAL INVESTMENT, %	
						WITH DEDUCT	WITHOUT DEDUCT		WITH DEDUCT	WITHOUT DEDUCT	WITH DEDUCT	WITHOUT DEDUCT	WITH DEDUCT	WITHOUT DEDUCT	WITH DEDUCT	WITHOUT DEDUCT	WITH DEDUCT	WITHOUT DEDUCT
1																		
2																		
3																		
4	7000	268000	5640500	3587300	2053200	10204700	13792000	8951200	(1253500)	(4840800)	(626750)	(2420400)	1046090	(747560)	1046090	(747560)		
5	7000	268000	5576300	3533800	2042500	10194000	13727800	8951200	(1242800)	(4776600)	(621400)	(2388300)	1051440	(715460)	2097530	(1463020)		
6	7000	268000	5512000	3480600	2031400	10182900	13663500	8951200	(1231700)	(4712300)	(615850)	(2356150)	1056990	(683310)	3154520	(2146330)		
7	7000	268000	5447700	3427200	2020500	10172000	13599200	8951200	(1220800)	(4648000)	(610400)	(2324000)	1062440	(651160)	4216960	(2797490)		
8	7000	268000	5383400	3373900	2009500	10161000	13534900	8951200	(1209800)	(4583700)	(604900)	(2291850)	1067940	(619010)	5284900	(3416500)		
9	7000	268000	5319000	3319900	1999100	10150600	13470500	8951200	(1199400)	(4519300)	(599700)	(2259650)	1073140	(586810)	6358040	(4003310)		
10	7000	268000	5254900	3267200	1987700	10139200	13406400	8951200	(1188000)	(4455200)	(594000)	(2227600)	1078840	(554760)	7436880	(4558070)		
11	5000	191400	4367000	2857000	1510000	8130000	10987000	6482700	(1647300)	(4504300)	(823650)	(2252150)	849190	(579310)	8286070	(5137380)		
12	5000	191400	4302800	2803800	1499000	8119000	10922800	6482700	(1636300)	(4440100)	(818150)	(2220050)	854690	(547210)	9140760	(5684590)		
13	5000	191400	4238500	2750300	1488200	8108200	10858500	6482700	(1625500)	(4375800)	(812750)	(2187900)	860090	(515060)	10000850	(6199650)		
14	5000	191400	4174200	2696900	1477300	6424500	9121400	6482700	58200	(2638700)	29100	(1319350)	29100	(1319350)	10029950	(7519000)	0.16	
15	5000	191400	4110000	2643600	1466400	6413600	9057200	6482700	69100	(2574500)	34550	(1287250)	34550	(1287250)	10064500	(8806250)	0.19	
16	3500	134000	3385800	2294300	1091500	4844200	7139500	4596200	(248000)	(2542300)	(124000)	(1271150)	(124000)	(1271150)	9940500	(10077400)		
17	3500	134000	3321500	2241100	1080400	4833100	7074200	4596200	(236900)	(2478000)	(118450)	(1239000)	(118450)	(1239000)	9822050	(11316400)		
18	3500	134000	3257200	2187600	1069600	4822300	7009900	4596200	(226100)	(2413700)	(113050)	(1206850)	(113050)	(1206850)	9709000	(12523250)		
19	3500	134000	3193000	2134400	1058600	4811300	6945700	4596200	(215100)	(2349500)	(107550)	(1174750)	(107550)	(1174750)	9601450	(13698000)		
20	3500	134000	3128700	2080900	1047800	4800500	6881400	4596200	(204300)	(2285200)	(102150)	(1142600)	(102150)	(1142600)	9499300	(14840600)		
21	1500	57400	2208300	1685300	523000	2567500	4252800	2011300	(556200)	(2241500)	(278100)	(1120750)	(278100)	(1120750)	9221200	(15961350)		
22	1500	57400	2144000	1632000	512000	2556500	4188500	2011300	(545200)	(2177200)	(272600)	(1088600)	(272600)	(1088600)	8948600	(17049950)		
23	1500	57400	2079800	1578600	501200	2545700	4124300	2011300	(534400)	(2113000)	(267200)	(1056500)	(267200)	(1056500)	8681400	(18106450)		
24	1500	57400	2015500	1525300	490200	2534700	4060000	2011300	(523400)	(2048700)	(261700)	(1024350)	(261700)	(1024350)	8419700	(19130800)		
25	1500	57400	1951200	1471900	479300	2523800	3995700	2011300	(512500)	(1984400)	(256250)	(992200)	(256250)	(992200)	8163450	(20123000)		
26	1500	57400	1887000	1418600	468400	2512900	3931500	2011300	(501600)	(1920200)	(250800)	(960100)	(250800)	(960100)	7912650	(21083100)		
27	1500	57400	1822700	1365200	457500	2502000	3867200	2011300	(490700)	(1855900)	(245350)	(927950)	(245350)	(927950)	7667300	(22011050)		
28	1500	57400	1758400	1311900	446500	2491000	3802900	2011300	(479700)	(1791600)	(239850)	(895800)	(239850)	(895800)	7427450	(22906850)		
29	1500	57400	1694100	1258500	435600	2480100	3738600	2011300	(468800)	(1727300)	(234400)	(863650)	(234400)	(863650)	7193050	(23770500)		
30	1500	57400	1629900	1205000	424900	2469400	3674400	2011300	(458100)	(1663100)	(229050)	(831550)	(229050)	(831550)	6964000	(24602050)		
31	1500	57400	1565600	1151800	413300	2458300	3610100	2011300	(447000)	(1598800)	(223500)	(799400)	(223500)	(799400)	6740500	(25401450)		
32	1500	57400	1501300	1098300	403000	2447500	3545800	2011300	(436200)	(1534500)	(218100)	(767250)	(218100)	(767250)	6522400	(26168700)		
33	1500	57400	1437000	1045100	391900	2436400	3481500	2011300	(425100)	(1470200)	(212550)	(735100)	(212550)	(735100)	6309850	(26903800)		
34	1500	57400	1372800	991600	381200	2425700	3417300	2011300	(414400)	(1406000)	(207200)	(703000)	(207200)	(703000)	6102650	(27606800)		
35	1500	57400	1308500	938400	370100	2414600	3353000	2011300	(403300)	(1341700)	(201650)	(670850)	(201650)	(670850)	5901000	(28277650)		
TOTAL	114000	4354000	101988600	69357300	33631300	169877200	238234500	148222400	(21654800)	(90012100)	(10827400)	(45006050)	5901000	(28277650)			AVG=	

Table B-148

PROCESS A. REGULATED POWER CO. ECONOMICS, 200 MW., EXISTING UNIT, 3.5% S IN COAL, 28-14-0 FERTILIZER PRODUCTION

FIXED INVESTMENT: $ 12520000

YEARS AFTER POWER UNIT START	ANNUAL OPERATION KW-HR/KW	TONS/YEAR FERTILIZER	TOTAL NH(3) SCRUBBING-FERTILIZER MFG. COST INCLUDING REGULATED ROI FOR POWER COMPANY, $/YEAR	NET FERTILIZER SALES REVENUE, $/YEAR	NET ANNUAL INCREASE (DECREASE) COST OF POWER, $	CUMULATIVE NET INCREASE (DECREASE) COST OF POWER, $	ALTERNATIVE OPERATING COST FOR WET-LIMESTONE PROCESS INCLUDING REGULATED ROI FOR POWER COMPANY, $/YEAR	ANNUAL SAVINGS (LOSS) USING NH(3) SCRUBBING-FERTILIZER INSTEAD OF WET-LIMESTONE SCRUBBING, $	CUMULATIVE SAVINGS (LOSS) USING NH(3) SCRUBBING-FERTILIZER INSTEAD OF WET-LIMESTONE SCRUBBING, $
1									
2									
3									
4									
5									
6									
7									
8									
9	7000	128600	7837300	5460400	2376900	2376900	1087900	(1289000)	(1289000)
10	7000	123600	7740700	5460400	2230300	4657200	1067700	(1212600)	(2501600)
11	5000	91700	6470000	3930300	2539700	7196900	947100	(1592600)	(4094200)
12	5000	91700	6373500	3930300	2443200	9640100	927000	(1516200)	(5510400)
13	5000	91700	6277000	3930300	2345700	11986800	906800	(1439900)	(7050300)
14	5000	91700	6180500	3930300	2250200	14237000	885600	(1363600)	(8413900)
15	5000	91700	6084000	3930300	2153700	16390700	866400	(1287300)	(9701200)
16	3500	64200	5074400	2774100	2300300	18691000	762900	(1537400)	(11238600)
17	3500	64200	4977900	2774100	2203800	20894800	742800	(1461000)	(12699600)
18	3500	64200	4881400	2774100	2107300	23002100	722600	(1384700)	(14084300)
19	3500	64200	4784800	2774100	2010700	25012800	702400	(1308300)	(15392600)
20	3500	64200	4688300	2774100	1914200	26927000	682200	(1232000)	(15524600)
21	1500	27600	3299600	1209400	2090200	29017200	553000	(1537200)	(18161800)
22	1500	27600	3203100	1209400	1993700	31010900	532800	(1460900)	(19622700)
23	1500	27600	3106600	1209400	1897200	32908100	512600	(1384600)	(21007300)
24	1500	27600	3010100	1209400	1800700	34708800	492400	(1308300)	(22315600)
25	1500	27600	2913600	1209400	1704200	36413000	472300	(1231900)	(23547500)
26	1500	27600	2817100	1209400	1607700	38020700	452100	(1155600)	(24703100)
27	1500	27600	2720500	1209400	1511100	39531800	431900	(1079200)	(25782300)
28	1500	27600	2624000	1209400	1414600	40946400	411700	(1002900)	(26785200)
29	1500	27600	2527500	1209400	1318100	42264500	391600	(926500)	(27711700)
30	1500	27600	2453000	1209400	1243600	43508100	371400	(872200)	(28583900)
31	1500	27600	2334500	1209400	1125100	44633200	351200	(773900)	(29357800)
32	1500	27600	2238000	1209400	1028600	45661800	331000	(697600)	(30055400)
33	1500	27600	2141500	1209400	932100	46593900	310900	(621200)	(30676600)
34	1500	27600	2045000	1209400	835600	47429500	290700	(544900)	(31221500)
35	1500	27600	1948400	1209400	739000	48168500	270500	(468500)	(31690000)
TOTAL	79000	1450700	110752300	62583800	48168500		16478500	(31690000)	

PRESENT WORTH IF DISCOUNTED AT 10% TO INITIAL YEAR 19423200 7219400

Table B-149

PROCESS A. REGULATED POWER CO. ECONOMICS, 500 MW., NEW UNIT, 2.0% S IN COAL, 28-14-0 FERTILIZER PRODUCTION

FIXED INVESTMENT: $ 16695000

YEARS AFTER POWER UNIT START	ANNUAL OPERATION KW-HR/KW	TONS/YEAR FERTILIZER	TOTAL NH(3) SCRUBBING-FERTILIZER MFG. COST INCLUDING REGULATED ROI FOR POWER COMPANY, $/YEAR	NET FERTILIZER SALES REVENUE, $/YEAR	NET ANNUAL INCREASE (DECREASE) COST OF POWER, $	CUMULATIVE NET INCREASE (DECREASE) COST OF POWER, $	ALTERNATIVE OPERATING COST FOR WET-LIMESTONE PROCESS INCLUDING REGULATED ROI FOR POWER COMPANY, $/YEAR	ANNUAL SAVINGS (LOSS) USING NH(3) SCRUBBING-FERTILIZER INSTEAD OF WET-LIMESTONE SCRUBBING, $	CUMULATIVE SAVINGS (LOSS) USING NH(3) SCRUBBING-FERTILIZER INSTEAD OF WET-LIMESTONE SCRUBBING, $
1	7000	173600	10062900	7301600	2761300	2761300	1800000	(961300)	(961300)
2	7000	173600	9963600	7301600	2662000	5423300	1772800	(889200)	(1850500)
3	7000	173600	9864400	7301600	2562800	7986100	1749100	(813700)	(2664200)
4	7000	173600	9765200	7301600	2463600	10449700	1718800	(744800)	(3409000)
5	7000	173600	9666000	7301600	2364400	12814100	1690600	(673800)	(4082800)
6	7000	173600	9566800	7301600	2265200	15079300	1663400	(601800)	(4684600)
7	7000	173600	9467600	7301600	2166000	17245300	1635900	(530100)	(5214700)
8	7000	173600	9368300	7301600	2066700	19312000	1608700	(458000)	(5672700)
9	7000	173600	9269100	7301600	1967500	21279500	1581200	(386300)	(6059000)
10	7000	173600	9169900	7301600	1868300	23147800	1553800	(314500)	(6373500)
11	5000	123900	7570500	5268200	2302300	25450100	1379800	(922500)	(7296000)
12	5000	123900	7471300	5268200	2203100	27653200	1352300	(850800)	(8146800)
13	5000	123900	7372100	5268200	2103900	29757100	1325100	(778800)	(8925600)
14	5000	123900	7272900	5268200	2004700	31761800	1297900	(706800)	(9632400)
15	5000	123900	7173600	5268200	1905400	33667200	1270400	(635000)	(10267400)
16	3500	86700	5909000	3721200	2187800	35855000	1114100	(1073700)	(11341100)
17	3500	86700	5809800	3721200	2088600	37943600	1086700	(1001900)	(12343000)
18	3500	86700	5710600	3721200	1989400	39933000	1059200	(930200)	(13273200)
19	3500	86700	5611400	3721200	1890200	41823200	1032000	(858200)	(14131400)
20	3500	86700	5512200	3721200	1791000	43614200	1004500	(786500)	(14917900)
21	1500	37200	3768000	1623000	2145000	45759200	827100	(1317900)	(16235800)
22	1500	37200	3668800	1623000	2045800	47805000	799800	(1246000)	(17481800)
23	1500	37200	3569600	1623000	1946600	49751600	772400	(1174200)	(18656000)
24	1500	37200	3470400	1623000	1847400	51599000	745100	(1102300)	(19758300)
25	1500	37200	3371200	1623000	1748200	53347200	717700	(1030500)	(20788800)
26	1500	37200	3272000	1623000	1649000	54996200	690400	(958600)	(21747400)
27	1500	37200	3172700	1623000	1549700	56545900	663000	(886700)	(22634100)
28	1500	37200	3073500	1623000	1450500	57996400	635500	(815000)	(23449100)
29	1500	37200	2974300	1623000	1351300	59347700	608300	(743000)	(24192100)
30	1500	37200	2875100	1623000	1252100	60599800	580800	(671300)	(24863400)
31	1500	37200	2775900	1623000	1152900	61752700	553600	(599300)	(25462700)
32	1500	37200	2676700	1623000	1053700	62806400	526100	(527600)	(25990300)
33	1500	37200	2577400	1623000	954400	63760800	498900	(455500)	(26445800)
34	1500	37200	2478200	1623000	855200	64616000	471400	(383800)	(26829600)
35	1500	37200	2379000	1623000	756000	65372000	444200	(311800)	(27141400)
TOTAL	135000	3347000	207680000	142308000	65372000		38230600	(27141400)	
PRESENT WORTH IF DISCOUNTED AT 10% TO INITIAL YEAR					21453300		14120000		

Table B-150

PROCESS A. REGULATED POWER CO. ECONOMICS, 500 MW., NEW UNIT, 3.5% S IN COAL, 28-14-0 FERTILIZER PRODUCTION

FIXED INVESTMENT: $ 21470000

YEARS AFTER POWER UNIT START	ANNUAL OPERATION KW-HR/KW	TONS/YEAR FERTILIZER	TOTAL NH(3) SCRUBBING-FERTILIZER MFG. COST INCLUDING REGULATED ROI FOR POWER COMPANY, $/YEAR	NET FERTILIZER SALES REVENUE, $/YEAR	NET ANNUAL INCREASE (DECREASE) COST OF POWER, $	CUMULATIVE NET INCREASE (DECREASE) COST OF POWER, $	ALTERNATIVE OPERATING COST FOR WET-LIMESTONE PROCESS INCLUDING REGULATED ROI FOR POWER COMPANY, $/YEAR	ANNUAL SAVINGS (LOSS) USING NH(3) SCRUBBING-FERTILIZER INSTEAD OF WET-LIMESTONE SCRUBBING, $	CUMULATIVE SAVINGS (LOSS) USING NH(3) SCRUBBING-FERTILIZER INSTEAD OF WET-LIMESTONE SCRUBBING, $
1	7000	303800	14736100	12492000	2244100	2244100	2150200	(93900)	(93900)
2	7000	303800	14608600	12492000	2116600	4360700	2119600	3000	(90900)
3	7000	303800	14480800	12492000	1988800	6349500	2089200	100400	9500
4	7000	303800	14353300	12492000	1861300	8210800	2058700	197400	206900
5	7000	303800	14225600	12492000	1733600	9944400	2028100	294500	501400
6	7000	303800	14098100	12492000	1606100	11550500	1997500	391400	892800
7	7000	303800	13970600	12492000	1478600	13029100	1967100	488500	1381300
8	7000	303800	13955200	12492000	1463200	14492300	1936600	473400	1854700
9	7000	303800	13715400	12492000	1223400	15715700	1906000	682600	2537300
10	7000	303800	13587700	12492000	1095700	16811400	1875600	779900	3317200
11	5000	217000	11025900	9051000	1974900	18786300	1640100	(334800)	2982400
12	5000	217000	10898400	9051000	1847400	20633700	1610000	(237400)	2745000
13	5000	217000	10770700	9051000	1719700	22353400	1579400	(140300)	2604700
14	5000	217000	10643200	9051000	1592200	23945600	1549000	(43200)	2561500
15	5000	217000	10515500	9051000	1464500	25410100	1518400	53900	2615400
16	3500	151900	8508800	6415000	2093800	27503900	1311600	(782200)	1833200
17	3500	151900	8381200	6415000	1966200	29470100	1281200	(685000)	1148200
18	3500	151900	8253500	6415000	1838500	31308600	1250600	(587900)	560300
19	3500	151900	8126000	6415000	1711000	33019600	1220100	(490900)	69400
20	3500	151900	7998300	6415000	1583300	34602900	1189700	(393600)	(324200)
21	1500	65300	5259200	2820000	2439200	37042100	952200	(1487000)	(1811200)
22	1500	65300	5131700	2820000	2311700	39353800	921600	(1390100)	(3201300)
23	1500	65300	5004000	2820000	2184000	41537800	891100	(1292900)	(4494200)
24	1500	65300	4876500	2820000	2056500	43594300	860700	(1195800)	(5690000)
25	1500	65300	4748800	2820000	1928800	45523100	830100	(1098700)	(6788700)
26	1500	65300	4621300	2820000	1801300	47324400	799500	(1001800)	(7790500)
27	1500	65300	4493800	2820000	1673800	48998200	769200	(904600)	(8695100)
28	1500	65300	4366100	2820000	1546100	50544300	738400	(807700)	(9502800)
29	1500	65300	4238600	2820000	1418600	51962900	708100	(710500)	(10213300)
30	1500	65300	4110800	2820000	1290800	53253700	677400	(613400)	(10826700)
31	1500	65300	3983300	2820000	1163300	54417000	647100	(516200)	(11342900)
32	1500	65300	3855800	2820000	1035800	55452800	616500	(419300)	(11762200)
33	1500	65300	3728100	2820000	908100	56360900	585900	(322200)	(12084400)
34	1500	65300	3600600	2820000	780600	57141500	555600	(225000)	(12309400)
35	1500	65300	3472900	2820000	652900	57794400	525000	(127900)	(12437300)
TOTAL	135000	5862000	302344400	244550000	57794400		45357100	(12437300)	
PRESENT WORTH IF DISCOUNTED AT 10% TO INITIAL YEAR					17156200		16864800		

Table B-151

PROCESS A, REGULATED POWER CO. ECONOMICS, 500 MW., EXISTING UNIT, 3.5% S IN COAL, 28-14-0 FERTILIZER

FIXED INVESTMENT: $ 22320000

YEARS AFTER POWER UNIT START	ANNUAL OPERATION KW-HR/KW	TONS/YEAR FERTILIZER	TOTAL NH(3) SCRUBBING-FERTILIZER MFG. COST INCLUDING REGULATED ROI FOR POWER COMPANY, $/YEAR	NET FERTILIZER SALES REVENUE, $/YEAR	NET ANNUAL INCREASE (DECREASE) COST OF POWER, $	CUMULATIVE NET INCREASE (DECREASE) COST OF POWER, $	ALTERNATIVE OPERATING COST FOR WET-LIMESTONE PROCESS INCLUDING REGULATED ROI FOR POWER COMPANY, $/YEAR	ANNUAL SAVINGS (LOSS) USING NH(3) SCRUBBING-FERTILIZER INSTEAD OF WET-LIMESTONE SCRUBBING, $	CUMULATIVE SAVINGS (LOSS) USING NH(3) SCRUBBING-FERTILIZER INSTEAD OF WET-LIMESTONE SCRUBBING, $
1									
2									
3									
4	7000	310800	15473600	12764600	2709000	2709000	2261500	(447500)	(447500)
5	7000	310800	15328400	12764600	2563800	5272800	2226100	(337700)	(785200)
6	7000	310800	15183400	12764600	2418800	7691600	2191000	(227800)	(1013000)
7	7000	310800	15038400	12764600	2273800	9965400	2155600	(118200)	(1131200)
8	7000	310800	14893200	12764600	2128600	12094000	2120500	(8100)	(1139300)
9	7000	310800	14748100	12764600	1983500	14077500	2085100	101600	(1037700)
10	7000	310800	14603100	12764600	1838500	15916000	2050000	211500	(826200)
11	5000	222000	11904100	9253000	2651100	18567100	1804000	(847100)	(1673300)
12	5000	222000	11758900	9253000	2505900	21073000	1768900	(737000)	(2410300)
13	5000	222000	11613700	9253000	2360700	23433700	1733500	(627200)	(3037500)
14	5000	222000	11468800	9253000	2215800	25649500	1698300	(517500)	(3555000)
15	5000	222000	11323800	9253000	2070800	27720300	1663000	(407800)	(3962800)
16	3500	155400	9206700	6561000	2645700	30366000	1447600	(1198100)	(5160900)
17	3500	155400	9061500	6561000	2500500	32866500	1412300	(1088200)	(6249100)
18	3500	155400	8916500	6561000	2355500	35222000	1377100	(978400)	(7227500)
19	3500	155400	8771600	6561000	2210600	37432600	1341800	(868800)	(8096300)
20	3500	155400	8626400	6561000	2065400	39498000	1306600	(758800)	(8855100)
21	1500	66800	6001200	2883800	3117400	42615400	1061200	(2056200)	(10911300)
22	1500	66800	5856200	2883800	2972400	45587800	1025900	(1946500)	(12857800)
23	1500	66800	5711200	2883800	2827400	48415200	990700	(1836700)	(14694500)
24	1500	66800	5566100	2883800	2682300	51097500	955400	(1726900)	(16421400)
25	1500	66800	5420900	2883800	2537100	53634600	920200	(1616900)	(18038300)
26	1500	66800	5275900	2883800	2392100	56026700	884900	(1507200)	(19545500)
27	1500	66800	5130900	2883800	2247100	58273800	849700	(1397400)	(20942900)
28	1500	66800	4985700	2883800	2101900	60375700	814300	(1287600)	(22230500)
29	1500	66800	4840600	2883800	1956800	62332500	779200	(1177600)	(23408100)
30	1500	66800	4695600	2883800	1811800	64144300	743800	(1068000)	(24476100)
31	1500	66800	4550600	2883800	1666800	65811100	708700	(958100)	(25434200)
32	1500	66800	4405400	2883800	1521600	67332700	673300	(848300)	(26282500)
33	1500	66800	4260200	2883800	1376400	68709100	638200	(738200)	(27020700)
34	1500	66800	4115300	2883800	1231500	69940600	602800	(628700)	(27649400)
35	1500	66800	3970300	2883800	1086500	71027100	567700	(518800)	(28168200)
TOTAL	114000	5064600	282706300	211679200	71027100		42858900	(28168200)	

PRESENT WORTH IF DISCOUNTED AT 10% TO INITIAL YEAR 22400000 16933200

Table B-152

PROCESS A. REGULATED POWER CO. ECONOMICS, 500 MW., NEW UNIT, 5.0% S IN COAL, 28-14-0 FERTILIZER PRODUCTION

FIXED INVESTMENT: $ 26130000

YEARS AFTER POWER UNIT START	ANNUAL OPERATION KW-HR/KW	TONS/YEAR FERTILIZER	TOTAL NH(3) SCRUBBING-FERTILIZER MFG. COST INCLUDING REGULATED ROI FOR POWER COMPANY, $/YEAR	NET FERTILIZER SALES REVENUE, $/YEAR	NET ANNUAL INCREASE (DECREASE) COST OF POWER, $	CUMULATIVE NET INCREASE (DECREASE) COST OF POWER, $	ALTERNATIVE OPERATING COST FOR WET-LIMESTONE PROCESS INCLUDING REGULATED ROI FOR POWER COMPANY, $/YEAR	ANNUAL SAVINGS (LOSS) USING NH(3) SCRUBBING-FERTILIZER INSTEAD OF WET-LIMESTONE SCRUBBING, $	CUMULATIVE SAVINGS (LOSS) USING NH(3) SCRUBBING-FERTILIZER INSTEAD OF WET-LIMESTONE SCRUBBING, $
1	7000	434000	19318200	17516200	802000	802000	2506500	1704500	1704500
2	7000	434000	19162900	17516200	646700	1448700	2473000	1826300	3530800
3	7000	434000	18007700	17516200	491500	1940200	2439300	1947800	5478600
4	7000	434000	17852300	17516200	336100	2276300	2405800	2069700	7548300
5	7000	434000	17697200	17516200	181000	2457300	2372100	2191100	9739400
6	7000	434000	17541800	17516200	25600	2482900	2338600	2313000	12052400
7	7000	434000	17386400	17516200	(129800)	2353100	2304900	2434700	14487100
8	7000	434000	17231200	17516200	(285000)	2068100	2271500	2556500	17043600
9	7000	434000	17075900	17516200	(440300)	1627600	2238000	2678300	19721900
10	7000	434000	16920700	17516200	(595500)	1032300	2204300	2799300	22521700
11	5000	309800	13684900	12726600	958300	1990600	1903900	945600	23467300
12	5000	309800	13529500	12726600	802900	2793500	1870200	1067300	24534600
13	5000	309800	13374400	12726600	647800	3441300	1836700	1188900	25723500
14	5000	309800	13219000	12726600	492400	3933700	1803000	1310600	27034100
15	5000	309800	13063800	12726600	337200	4270900	1769500	1432300	28466400
16	3500	217000	10534500	9051000	1483500	5754400	1512100	28600	28495000
17	3500	217000	10379200	9051000	1328200	7082600	1478400	150200	28645200
18	3500	217000	10224000	9051000	1173000	8255600	1444900	271900	28917100
19	3500	217000	10068600	9051000	1017600	9273200	1411300	393700	29310800
20	3500	217000	9913500	9051000	862500	10135700	1377800	515300	29826100
21	1500	92800	6451700	3977400	2474300	12610000	1078200	(1396100)	28430000
22	1500	92800	6296300	3977400	2318900	14928900	1044700	(1274200)	27155800
23	1500	92800	6141100	3977400	2163700	17092600	1011900	(1151800)	26004000
24	1500	92800	5985800	3977400	2008400	19101000	977500	(1030900)	24973100
25	1500	92800	5830600	3977400	1853200	20954200	944000	(909200)	24063900
26	1500	92800	5675200	3977400	1697800	22652000	910300	(787500)	23276400
27	1500	92800	5519800	3977400	1542400	24194400	876800	(665600)	22610800
28	1500	92800	5364700	3977400	1387300	25581700	843100	(544200)	22066600
29	1500	92800	5209300	3977400	1231900	26813600	809600	(422300)	21644300
30	1500	92800	5054100	3977400	1076700	27890300	776200	(300500)	21343800
31	1500	92800	4898800	3977400	921400	28811700	742500	(178900)	21164900
32	1500	92800	4743400	3977400	766000	29577700	708800	(57200)	21107700
33	1500	92800	4588200	3977400	610800	30188500	675300	64500	21172200
34	1500	92800	4432800	3977400	455400	30643900	641800	186400	21358600
35	1500	92800	4277700	3977400	300300	30944200	608100	307800	21666400
TOTAL	135000	8366000	374655200	343711000	30944200		52610600	21666400	

PRESENT WORTH IF DISCOUNTED AT 10% TO INITIAL YEAR 5324900 19662100

Table B-153

PROCESS A. REGULATED POWER CO. ECONOMICS, 1000 MW., NEW UNIT, 3.5% S IN COAL, 28-14-0 FERTILIZER PRODUCTION

FIXED INVESTMENT: $ 34500000

YEARS AFTER POWER UNIT START	ANNUAL OPERATION KW-HR/KW	TONS/YEAR FERTILIZER	TOTAL NH(3) SCRUBBING-FERTILIZER MFG. COST INCLUDING REGULATED ROI FOR POWER COMPANY, $/YEAR	NET FERTILIZER SALES REVENUE, $/YEAR	NET ANNUAL INCREASE (DECREASE) COST OF POWER, $	CUMULATIVE NET INCREASE (DECREASE) COST OF POWER, $	ALTERNATIVE OPERATING COST FOR WET-LIMESTONE PROCESS INCLUDING REGULATED ROI FOR POWER COMPANY, $/YEAR	ANNUAL SAVINGS (LOSS) USING NH(3) SCRUBBING-FERTILIZER INSTEAD OF WET-LIMESTONE SCRUBBING, $	CUMULATIVE SAVINGS (LOSS) USING NH(3) SCRUBBING-FERTILIZER INSTEAD OF WET-LIMESTONE SCRUBBING, $
1	7000	587500	24062600	23270900	791700	791700	3362400	2570700	2570700
2	7000	587500	23857500	23270900	586600	1378300	3317000	2730400	5301100
3	7000	587500	23652600	23270900	381700	1760000	3271900	2890200	8191300
4	7000	587500	23447500	23270900	176600	1936600	3226500	3049900	11241200
5	7000	587500	23242500	23270900	(28400)	1908200	3181200	3209600	14450800
6	7000	587500	23037400	23270900	(233500)	1674700	3135800	3369300	17820100
7	7000	587500	22832500	23270900	(438400)	1236300	3090700	3529100	21349200
8	7000	587500	22627400	23270900	(643500)	592800	3045400	3688900	25038100
9	7000	587500	22422300	23270900	(848600)	(255800)	3000000	3848600	28886700
10	7000	587500	22217400	23270900	(1053500)	(1309300)	2954900	4008400	32895100
11	5000	419700	17967000	16972700	994300	(315000)	2565100	1570800	34465900
12	5000	419700	17762000	16972700	789300	474300	2519800	1730500	36196400
13	5000	419700	17557100	16972700	584400	1058700	2474500	1890100	38086500
14	5000	419700	17352000	16972700	379300	1438000	2429300	2050000	40136500
15	5000	419700	17146900	16972700	174200	1612200	2384000	2209800	42346300
16	3500	293800	13826000	12098700	1727300	3339500	2053500	326200	42672500
17	3500	293800	13621100	12098700	1522400	4861900	2008400	486000	43158500
18	3500	293800	13416000	12098700	1317300	6179200	1963100	645800	43804300
19	3500	293800	13211000	12098700	1112300	7291500	1917700	805400	44609700
20	3500	293800	13006100	12098700	907400	8198900	1872400	965000	45574700
21	1500	126300	8467100	5366500	3100600	11299500	1496500	(1604100)	43970600
22	1500	126300	8262000	5366500	2895500	14195000	1451200	(1444300)	42526300
23	1500	126300	8057100	5366500	2690600	16885600	1405800	(1284800)	41241500
24	1500	126300	7852000	5366500	2485500	19371100	1360700	(1124800)	40116700
25	1500	126300	7646900	5366500	2280400	21651500	1315400	(965000)	39151700
26	1500	126300	7441900	5366500	2075400	23726900	1270000	(805400)	38346300
27	1500	126300	7237000	5366500	1870500	25597400	1224700	(645800)	37700500
28	1500	126300	7031900	5366500	1665400	27262800	1179500	(485900)	37214600
29	1500	126300	6826800	5366500	1460300	28723100	1134200	(326100)	36888500
30	1500	126300	6621900	5366500	1255400	29978500	1088800	(166600)	36721900
31	1500	126300	6416800	5366500	1050300	31028800	1043700	(6600)	36715300
32	1500	126300	6211700	5366500	845200	31874000	998400	153200	36868500
33	1500	126300	6006900	5366500	640400	32514400	953000	312600	37181100
34	1500	126300	5801800	5366500	435300	32949700	907700	472400	37653500
35	1500	126300	5596700	5366500	230200	33179900	862500	632300	38285800
TOTAL	135000	11337000	491743400	458563500	33179900		71465700	38285800	
PRESENT WORTH IF DISCOUNTED AT 10% TO INITIAL YEAR					4594800		26463500		

Table B-154

PROCESS A, REGULATED POWER CO. ECONOMICS, 1000 MW., EXISTING UNIT, 3.5% S IN COAL, 28-14-0 FERTILIZER PRODUCTION

FIXED INVESTMENT: $ 36550000

YEARS AFTER POWER UNIT START	ANNUAL OPERATION KW-HR/KW	TONS/YEAR FERTILIZER	TOTAL NH(3) SCRUBBING-FERTILIZER MFG. COST INCLUDING REGULATED ROI FOR POWER COMPANY, $/YEAR	NET FERTILIZER SALES REVENUE, $/YEAR	NET ANNUAL INCREASE (DECREASE) COST OF POWER, $	CUMULATIVE NET INCREASE (DECREASE) COST OF POWER, $	ALTERNATIVE OPERATING COST FOR WET-LIMESTONE PROCESS INCLUDING REGULATED ROI FOR POWER COMPANY, $/YEAR	ANNUAL SAVINGS (LOSS) USING NH(3) SCRUBBING-FERTILIZER INSTEAD OF WET-LIMESTONE SCRUBBING, $	CUMULATIVE SAVINGS (LOSS) USING NH(3) SCRUBBING-FERTILIZER INSTEAD OF WET-LIMESTONE SCRUBBING, $
1									
2									
3									
4	7000	607600	25799300	24018400	1780900	1780900	3587300	1806400	1806400
5	7000	607600	25561800	24018400	1543400	3324300	3533800	1990400	3796800
6	7000	607600	25324200	24018400	1305800	4630100	3480600	2174800	5971600
7	7000	607600	25086500	24018400	1068100	5698200	3427200	2359100	8330700
8	7000	607600	24848900	24018400	830500	6528700	3373900	2543400	10874100
9	7000	607600	24611400	24018400	593000	7121700	3319900	2726900	13601000
10	7000	607600	24373900	24018400	355500	7477200	3267200	2911700	16512700
11	5000	433800	19795500	17508200	2287300	9764500	2857000	569700	17082400
12	5000	433800	19557800	17508200	2049600	11814100	2803800	754200	17836600
13	5000	433800	19320300	17508200	1812100	13626200	2750300	938200	18774800
14	5000	433800	19082700	17508200	1574500	15200700	2696900	1122400	19897200
15	5000	433800	18845200	17508200	1337000	16537700	2643600	1306600	21203800
16	3500	303700	15264800	12488100	2776700	19314400	2294300	(482400)	20721400
17	3500	303700	15027000	12488100	2538900	21853300	2241100	(297800)	20423600
18	3500	303700	14789500	12488100	2301400	24154700	2187600	(113800)	20309800
19	3500	303700	14551900	12488100	2063800	26218500	2134400	70600	20380400
20	3500	303700	14314400	12488100	1826300	28044800	2080900	254600	20635000
21	1500	130100	9429100	5522700	3906400	31951200	1685300	(2221100)	18413900
22	1500	130100	9191300	5522700	3668600	35619800	1632000	(2036600)	16377300
23	1500	130100	8953800	5522700	3431100	39050900	1578600	(1852500)	14524800
24	1500	130100	8581900	5522700	3059200	42110100	1525300	(1533900)	12990900
25	1500	130100	8478700	5522700	2956000	45066100	1471900	(1484100)	11506800
26	1500	130100	8241200	5522700	2718500	47784600	1418600	(1299900)	10206900
27	1500	130100	8003400	5522700	2480700	50265300	1365200	(1115500)	9091400
28	1500	130100	7765900	5522700	2243200	52508500	1311900	(931300)	8160100
29	1500	130100	7528400	5522700	2005700	54514200	1258500	(747200)	7412900
30	1500	130100	7290800	5522700	1768100	56282300	1205000	(563100)	6849800
31	1500	130100	7053300	5522700	1530600	57812900	1151800	(378800)	6471000
32	1500	130100	6815500	5522700	1292800	59105700	1098300	(194500)	6276500
33	1500	130100	6578000	5522700	1055300	60161000	1045100	(10200)	6266300
34	1500	130100	6340500	5522700	817800	60978800	991600	173900	6440100
35	1500	130100	6102900	5522700	580200	61559000	938400	358200	6798300
TOTAL	114000	9892200	462509800	400950800	61559000		68357300	6798300	
PRESENT WORTH IF DISCOUNTED AT 10% TO INITIAL YEAR					16058000		26919700		

Table B-155

PROCESS B. REGULATED POWER CO. ECONOMICS, 200 MW., EXISTING UNIT, 3.5% S IN COAL, 26-19-0 FERTILIZER PRODUCTION

FIXED INVESTMENT: $ 11428000

YEARS AFTER POWER UNIT START	ANNUAL OPERATION KW-HR/KW	TONS/YEAR FERTILIZER	TOTAL NH(3) SCRUBBING-FERTILIZER MFG. COST INCLUDING REGULATED ROI FOR POWER COMPANY, $/YEAR	NET FERTILIZER SALES REVENUE, $/YEAR	NET ANNUAL INCREASE (DECREASE) COST OF POWER, $	CUMULATIVE NET INCREASE (DECREASE) COST OF POWER, $	ALTERNATIVE OPERATING COST FOR WET-LIMESTONE PROCESS INCLUDING REGULATED ROI FOR POWER COMPANY, $/YEAR	ANNUAL SAVINGS (LOSS) USING NH(3) SCRUBBING-FERTILIZER INSTEAD OF WET-LIMESTONE SCRUBBING, $	CUMULATIVE SAVINGS (LOSS) USING NH(3) SCRUBBING-FERTILIZER INSTEAD OF WET-LIMESTONE SCRUBBING, $
1									
2									
3									
4									
5									
6									
7									
8									
9	7000	97100	6755000	4386000	2369000	2369000	1087900	(1281100)	(1281100)
10	7000	97100	6667000	4386000	2281000	4650000	1067700	(1213300)	(2494400)
11	5000	69500	5629600	3162300	2467300	7117300	947100	(1520200)	(4014600)
12	5000	69500	5541600	3162300	2379300	9496600	927000	(1452300)	(5466900)
13	5000	69500	5453600	3162300	2291300	11787900	906800	(1384500)	(6851400)
14	5000	69500	5365600	3162300	2203300	13991200	886600	(1316700)	(8168100)
15	5000	69500	5277600	3162300	2115300	16106500	866400	(1248900)	(9417000)
16	3500	48600	4447200	2225400	2221800	18328300	762900	(1458900)	(10875900)
17	3500	48600	4359300	2225400	2133900	20462200	742800	(1391100)	(12267000)
18	3500	48600	4271300	2225400	2045900	22508100	722600	(1323300)	(13590300)
19	3500	48600	4183300	2225400	1957900	24466000	702400	(1255500)	(14845800)
20	3500	48600	4095300	2225400	1869900	26335900	682200	(1187700)	(16033500)
21	1500	20800	2944000	963000	1981000	28316900	553000	(1428000)	(17461500)
22	1500	20800	2856000	963000	1893000	30209900	532800	(1360200)	(18821700)
23	1500	20800	2768000	963000	1805000	32014900	512600	(1292400)	(20114100)
24	1500	20800	2680100	963000	1717100	33732000	492400	(1224700)	(21338800)
25	1500	20800	2592100	963000	1629100	35361100	472300	(1156800)	(22495600)
26	1500	20800	2504100	963000	1541100	36902200	452100	(1089000)	(23584600)
27	1500	20800	2416100	963000	1453100	38355300	431900	(1021200)	(24605800)
28	1500	20800	2328100	963000	1365100	39720400	411700	(953400)	(25559200)
29	1500	20800	2240100	963000	1277100	40997500	391600	(885500)	(26444700)
30	1500	20800	2152200	963000	1189200	42186700	371400	(817800)	(27262500)
31	1500	20800	2064200	963000	1101200	43287900	351200	(750000)	(28012500)
32	1500	20800	1976200	963000	1013200	44301100	331000	(682200)	(28694700)
33	1500	20800	1888200	963000	925200	45226300	310900	(614300)	(29309000)
34	1500	20800	1800200	963000	837200	46063500	290700	(546500)	(29855500)
35	1500	20800	1712200	963000	749200	46812700	270500	(478700)	(30334200)
TOTAL	79000	1096700	96968200	50155500	46812700		16478500	(30334200)	
PRESENT WORTH IF DISCOUNTED AT 10% TO INITIAL YEAR					18957200		7219400		

Table B-156

PROCESS B. REGULATED POWER CO. ECONOMICS, 500 MW., NEW UNIT, 2.0% S IN COAL, 26-19-0 FERTILIZER PRODUCTION

FIXED INVESTMENT: $ 15574000

YEARS AFTER POWER UNIT START	ANNUAL OPERATION KW-HR/ KW	TONS/YEAR FERTILIZER	TOTAL NH(3) SCRUBBING-FERTILIZER MFG. COST INCLUDING REGULATED ROI FOR POWER COMPANY, $/YEAR	NET FERTILIZER SALES REVENUE, $/YEAR	NET ANNUAL INCREASE (DECREASE) COST OF POWER, $	CUMULATIVE NET INCREASE (DECREASE) COST OF POWER, $	ALTERNATIVE OPERATING COST FOR WET-LIMESTONE PROCESS INCLUDING REGULATED ROI FOR POWER COMPANY, $/YEAR	ANNUAL SAVINGS (LOSS) USING NH(3) SCRUBBING-FERTILIZER INSTEAD OF WET-LIMESTONE SCRUBBING, $	CUMULATIVE SAVINGS (LOSS) USING NH(3) SCRUBBING-FERTILIZER INSTEAD OF WET-LIMESTONE SCRUBBING, $
1	7000	131500	9788200	5896500	2891700	2891700	1800000	(1091700)	(1091700)
2	7000	131500	8695600	5896500	2799100	5690800	1772800	(1026300)	(2118000)
3	7000	131500	8603100	5896500	2706600	8397400	1749100	(957500)	(3075500)
4	7000	131500	8510500	5896500	2614000	11011400	1718800	(895200)	(3970700)
5	7000	131500	8417900	5896500	2521400	13532800	1690600	(830800)	(4801500)
6	7000	131500	8325400	5896500	2428900	15961700	1663400	(765500)	(5567000)
7	7000	131500	8232800	5896500	2336300	18298000	1635900	(700400)	(6267400)
8	7000	131500	8140300	5896500	2243800	20541800	1608700	(635100)	(6902500)
9	7000	131500	8047700	5896500	2151200	22693000	1581200	(570000)	(7472500)
10	7000	131500	7955100	5896500	2058600	24751600	1553800	(504800)	(7977300)
11	5000	93900	6639700	4246200	2393500	27145100	1379800	(1013700)	(8991000)
12	5000	93900	6547100	4246200	2300900	29446000	1352300	(948600)	(9939600)
13	5000	93900	6454600	4246200	2208400	31654400	1325100	(883300)	(10822900)
14	5000	93900	6362000	4246200	2115800	33770200	1297900	(817900)	(11640800)
15	5000	93900	6269400	4246200	2023200	35793400	1270400	(752800)	(12393600)
16	3500	65800	5222000	2997200	2224800	38018200	1114100	(1110700)	(13504300)
17	3500	65800	5129400	2997200	2132200	40150400	1086700	(1045500)	(14549800)
18	3500	65800	5036800	2997200	2039600	42190000	1059200	(980400)	(15530200)
19	3500	65800	4944300	2997200	1947100	44137100	1032000	(915100)	(16445300)
20	3500	65800	4851700	2997200	1854500	45991600	1004500	(850000)	(17295300)
21	1500	28200	3397500	1301400	2096100	48087700	827100	(1269000)	(18564300)
22	1500	28200	3304900	1301400	2003500	50091200	799800	(1203700)	(19768000)
23	1500	28200	3212400	1301400	1911000	52002200	772400	(1138600)	(20906600)
24	1500	28200	3119800	1301400	1818400	53820600	745100	(1073300)	(21979900)
25	1500	28200	3027200	1301400	1725800	55546400	717700	(1008100)	(22988000)
26	1500	28200	2934700	1301400	1633300	57179700	690400	(942900)	(23930900)
27	1500	28200	2842100	1301400	1540700	58720400	663000	(877700)	(24808600)
28	1500	28200	2749600	1301400	1448200	60168600	635500	(812700)	(25621300)
29	1500	28200	2657000	1301400	1355600	61524200	608300	(747300)	(26368600)
30	1500	28200	2564400	1301400	1263000	62787200	580800	(682200)	(27050800)
31	1500	28200	2471900	1301400	1170500	63957700	553600	(616900)	(27667700)
32	1500	28200	2379300	1301400	1077900	65035600	526100	(551800)	(28219500)
33	1500	28200	2286800	1301400	985400	66021000	498900	(486500)	(28706000)
34	1500	28200	2194200	1301400	892800	66913800	471400	(421400)	(29127400)
35	1500	28200	2101600	1301400	800200	67714000	444200	(356000)	(29483400)
TOTAL	135000	2536500	182417000	114703000	67714000		38230600	(29483400)	
PRESENT WORTH IF DISCOUNTED AT 10% TO INITIAL YEAR					22536800		14120000		

Table B-157

PROCESS B. REGULATED POWER CO. ECONOMICS, 500 MW., NEW UNIT, 3.5% S IN COAL, 26-19-0 FERTILIZER PRODUCTION

FIXED INVESTMENT: $ 19689000

YEARS AFTER POWER UNIT START	ANNUAL OPERATION KW-HR/KW	TONS/YEAR FERTILIZER	TOTAL NH(3) SCRUBBING-FERTILIZER MFG. COST INCLUDING REGULATED ROI FOR POWER COMPANY, $/YEAR	NET FERTILIZER SALES REVENUE, $/YEAR	NET ANNUAL INCREASE (DECREASE) COST OF POWER, $	CUMULATIVE NET INCREASE (DECREASE) COST OF POWER, $	ALTERNATIVE OPERATING COST FOR WET-LIMESTONE PROCESS INCLUDING REGULATED ROI FOR POWER COMPANY, $/YEAR	ANNUAL SAVINGS (LOSS) USING NH(3) SCRUBBING-FERTILIZER INSTEAD OF WET-LIMESTONE SCRUBBING, $	CUMULATIVE SAVINGS (LOSS) USING NH(3) SCRUBBING-FERTILIZER INSTEAD OF WET-LIME-STONE SCRUBBING, $
1	7000	230000	12487800	10129200	2358600	2358600	2150200	(208400)	(208400)
2	7000	230000	12370700	10129200	2241500	4600100	2119600	(121900)	(330300)
3	7000	230000	12253600	10129200	2124400	6724500	2089200	(35200)	(365500)
4	7000	230000	12136500	10129200	2007300	8731800	2058700	51400	(314100)
5	7000	230000	12019400	10129200	1890200	10622000	2028100	137900	(176200)
6	7000	230000	11902300	10129200	1773100	12395100	1997500	224400	48200
7	7000	230000	11785200	10129200	1656000	14051100	1967100	311100	359300
8	7000	230000	11668000	10129200	1538800	15589900	1936600	397800	757100
9	7000	230000	11551000	10129200	1421800	17011700	1906000	484200	1241300
10	7000	230000	11433900	10129200	1304700	18316400	1875600	570900	1812200
11	5000	164300	9461200	7317900	2143300	20459700	1640100	(503200)	1309000
12	5000	164300	9344100	7317900	2026200	22485900	1610000	(416200)	892800
13	5000	164300	9226900	7317900	1909000	24394900	1579400	(329600)	563200
14	5000	164300	9109900	7317900	1792000	26186900	1549000	(243000)	320200
15	5000	164300	8992700	7317900	1674800	27861700	1518400	(156400)	163800
16	3500	115000	7355700	5173900	2181800	30043500	1311600	(870200)	(706400)
17	3500	115000	7238600	5173900	2064700	32108200	1281200	(783500)	(1489900)
18	3500	115000	7121500	5173900	1947600	34055800	1250600	(697000)	(2186900)
19	3500	115000	7004400	5173900	1830500	35886300	1220100	(610400)	(2797300)
20	3500	115000	6887300	5173900	1713400	37599700	1189700	(523700)	(3321000)
21	1500	49300	4628200	2257000	2371200	39970900	952200	(1419000)	(4740000)
22	1500	49300	4511100	2257000	2254100	42225000	921600	(1332500)	(6072500)
23	1500	49300	4394000	2257000	2137000	44362000	891100	(1245900)	(7318400)
24	1500	49300	4276900	2257000	2019900	46381900	860700	(1159200)	(8477600)
25	1500	49300	4159800	2257000	1902800	48284700	830100	(1072700)	(9550300)
26	1500	49300	4042700	2257000	1785700	50070400	799500	(986200)	(10536500)
27	1500	49300	3925600	2257000	1668600	51739000	769200	(899400)	(11435900)
28	1500	49300	3808500	2257000	1551500	53290500	738400	(813100)	(12249000)
29	1500	49300	3691400	2257000	1434400	54724900	708100	(726300)	(12975300)
30	1500	49300	3574300	2257000	1317300	56042200	677400	(639900)	(13615200)
31	1500	49300	3457200	2257000	1200200	57242400	647100	(553100)	(14168300)
32	1500	49300	3340100	2257000	1083100	58325500	616500	(466600)	(14634900)
33	1500	49300	3223000	2257000	966000	59291500	585900	(380100)	(15015000)
34	1500	49300	3105900	2257000	848900	60140400	555600	(293300)	(15308300)
35	1500	49300	2988800	2257000	731800	60872200	525000	(206800)	(15515100)
TOTAL	135000	4436000	258478200	197606000	60872200		45357100	(15515100)	
PRESENT WORTH IF DISCOUNTED AT 10% TO INITIAL YEAR					18404200		16864800		

Table B-158

PROCESS B. REGULATED POWER CO. ECONOMICS, 500 MW., EXISTING UNIT, 3.5% S IN COAL, 26-19-0 FERTILIZER PRODUCTION

FIXED INVESTMENT: $ 20191000

YEARS AFTER POWER UNIT START	ANNUAL OPERATION KW-HR/KW	TONS/YEAR FERTILIZER	TOTAL NH(3) SCRUBBING-FERTILIZER MFG. COST INCLUDING REGULATED ROI FOR POWER COMPANY, $/YEAR	NET FERTILIZER SALES REVENUE, $/YEAR	NET ANNUAL INCREASE (DECREASE) COST OF POWER, $	CUMULATIVE NET INCREASE (DECREASE) COST OF POWER, $	ALTERNATIVE OPERATING COST FOR WET-LIMESTONE PROCESS INCLUDING REGULATED ROI FOR POWER COMPANY, $/YEAR	ANNUAL SAVINGS (LOSS) USING NH(3) SCRUBBING-FERTILIZER INSTEAD OF WET-LIMESTONE SCRUBBING, $	CUMULATIVE SAVINGS (LOSS) USING NH(3) SCRUBBING-FERTILIZER INSTEAD OF WET-LIMESTONE SCRUBBING, $
1									
2									
3									
4	7000	235800	13001800	10375200	2626600	2626600	2261500	(365100)	(365100)
5	7000	235800	12870600	10375200	2495400	5122000	2226100	(269300)	(634400)
6	7000	235800	12739300	10375200	2364100	7486100	2191000	(173100)	(807500)
7	7000	235800	12608100	10375200	2232900	9719000	2155600	(77300)	(884800)
8	7000	235800	12476800	10375200	2101600	11820600	2120500	18900	(865900)
9	7000	235800	12345600	10375200	1970400	13791000	2085100	114700	(751200)
10	7000	235800	12204300	10375200	1829100	15620100	2050000	220900	(530300)
11	5000	168200	10056700	7486600	2570100	18190200	1804000	(766100)	(1296400)
12	5000	168200	9925400	7486600	2438800	20629000	1768900	(669900)	(1966300)
13	5000	168200	9794200	7486600	2307600	22936600	1733500	(574100)	(2540400)
14	5000	168200	9662900	7486600	2176300	25112900	1698300	(478000)	(3018400)
15	5000	168200	9531700	7486600	2045100	27158000	1663000	(382100)	(3400500)
16	3500	117900	7830600	5300800	2529800	29687800	1447600	(1082200)	(4482700)
17	3500	117900	7699300	5300800	2398500	32086300	1412300	(986200)	(5468900)
18	3500	117900	7568100	5300800	2267300	34353600	1377100	(890200)	(6359100)
19	3500	117900	7436800	5300800	2136000	36489600	1341800	(794200)	(7153300)
20	3500	117900	7305600	5300800	2004800	38494400	1306600	(698200)	(7851500)
21	1500	50500	4964500	2310400	2654100	41148500	1061200	(1592900)	(9444400)
22	1500	50500	4833300	2310400	2522900	43671400	1025900	(1497000)	(10941400)
23	1500	50500	4702000	2310400	2391600	46063000	990700	(1400900)	(12342300)
24	1500	50500	4570800	2310400	2260400	48323400	955400	(1305000)	(13647300)
25	1500	50500	4439500	2310400	2129100	50452500	920200	(1208900)	(14856200)
26	1500	50500	4308300	2310400	1997900	52450400	884900	(1113000)	(15969200)
27	1500	50500	4177000	2310400	1866600	54317000	849700	(1016900)	(16986100)
28	1500	50500	4045800	2310400	1735400	56052400	814300	(921100)	(17907200)
29	1500	50500	3914500	2310400	1604100	57656500	779200	(824900)	(18732100)
30	1500	50500	3783300	2310400	1472900	59129400	743800	(729100)	(19461200)
31	1500	50500	3652000	2310400	1341600	60471000	708700	(632900)	(20094100)
32	1500	50500	3520800	2310400	1210400	61681400	673300	(537100)	(20631200)
33	1500	50500	3389500	2310400	1079100	62760500	638200	(440900)	(21072100)
34	1500	50500	3258300	2310400	947900	63708400	502800	(345100)	(21417200)
35	1500	50500	3127200	2310400	816800	64525200	567700	(249100)	(21666300)
TOTAL	114000	3838600	235744600	171219400	64525200		42858900	(21666300)	
PRESENT WORTH IF DISCOUNTED AT 10% TO INITIAL YEAR					21364600		16933200		

Table B-159

PROCESS B. REGULATED POWER CO. ECONOMICS, 500 MW., NEW UNIT, 5.0% S IN COAL, 26-19-0 FERTILIZER PRODUCTION

FIXED INVESTMENT: $ 23525000

YEARS AFTER POWER UNIT START	ANNUAL OPERATION KW-HR/KW	TONS/YEAR FERTILIZER	TOTAL NH(3) SCRUBBING-FERTILIZER MFG. COST INCLUDING REGULATED ROI FOR POWER COMPANY, $/YEAR	NET FERTILIZER SALES REVENUE, $/YEAR	NET ANNUAL INCREASE (DECREASE) COST OF POWER, $	CUMULATIVE NET INCREASE (DECREASE) COST OF POWER, $	ALTERNATIVE OPERATING COST FOR WET-LIMESTONE PROCESS INCLUDING REGULATED ROI FOR POWER COMPANY, $/YEAR	ANNUAL SAVINGS (LOSS) USING NH(3) SCRUBBING-FERTILIZER INSTEAD OF WET-LIMESTONE SCRUBBING, $	CUMULATIVE SAVINGS (LOSS) USING NH(3) SCRUBBING-FERTILIZER INSTEAD OF WET-LIMESTONE SCRUBBING, $
1	7000	328600	15559800	14264500	1295300	1295300	2506500	1211200	1211200
2	7000	328600	15420000	14264500	1155500	2450800	2473000	1317500	2528700
3	7000	328600	15280200	14264500	1015700	3466500	2439300	1423600	3952300
4	7000	328600	15140500	14264500	876000	4342500	2405800	1529800	5482100
5	7000	328600	15000700	14264500	736200	5078700	2372100	1635900	7118000
6	7000	328600	14860900	14264500	596400	5675100	2338600	1742200	8860200
7	7000	328600	14721100	14264500	456600	6131700	2304900	1848300	10708500
8	7000	328600	14581400	14264500	316900	6448600	2271500	1954600	12663100
9	7000	328600	14441600	14264500	177100	6625700	2238000	2060900	14724000
10	7000	328600	14301800	14264500	37300	6663000	2204300	2167000	16891000
11	5000	234700	11662000	10329100	1332900	7995900	1903900	571000	17462000
12	5000	234700	11522300	10329100	1193200	9189100	1870200	677000	18139000
13	5000	234700	11382500	10329100	1053400	10242500	1836700	783300	18922300
14	5000	234700	11242700	10329100	913600	11156100	1803000	889400	19811700
15	5000	234700	11102900	10329100	773800	11929900	1769500	995700	20807400
16	3500	164300	9030100	7317900	1712200	13642100	1512100	(200100)	20607300
17	3500	164300	8890300	7317900	1572400	15214500	1478400	(94000)	20513300
18	3500	164300	8750500	7317900	1432600	16647100	1444900	12300	20525600
19	3500	164300	8610700	7317900	1292800	17939900	1411300	118500	20644100
20	3500	164300	8471000	7317900	1153100	19093000	1377800	224700	20868800
21	1500	70400	5621900	3201800	2420100	21513100	1078200	(1341900)	19526900
22	1500	70400	5482100	3201800	2280300	23793400	1044700	(1235600)	18291300
23	1500	70400	5342300	3201800	2140500	25933900	1011900	(1128600)	17162700
24	1500	70400	5202600	3201800	2000800	27934700	977500	(1023300)	16139400
25	1500	70400	5062800	3201800	1861000	29795700	944000	(917000)	15222400
26	1500	70400	4923000	3201800	1721200	31516900	910300	(810900)	14411500
27	1500	70400	4783200	3201800	1581400	33098300	876800	(704600)	13706900
28	1500	70400	4643400	3201800	1441600	34539900	843100	(598500)	13108400
29	1500	70400	4503700	3201800	1301900	35841800	809600	(492300)	12616100
30	1500	70400	4363900	3201800	1162100	37003900	776200	(385900)	12230200
31	1500	70400	4224100	3201800	1022300	38026200	742500	(279800)	11950400
32	1500	70400	4084300	3201800	882500	38908700	708800	(173700)	11776700
33	1500	70400	3944600	3201800	742800	39651500	675300	(67500)	11709200
34	1500	70400	3804800	3201800	603000	40254500	641800	38800	11748000
35	1500	70400	3665000	3201800	463200	40717700	608100	144900	11892900
TOTAL	135000	6337000	319624700	278907000	40717700		52610600	11892900	
PRESENT WORTH IF DISCOUNTED AT 10% TO INITIAL YEAR					9563800		19662100		

Table B-160

PROCESS B. REGULATED POWER CO. ECONOMICS, 1000 MW., NEW UNIT, 3.5% S IN COAL, 26-19-0 FERTILIZER PRODUCTION

FIXED INVESTMENT: $ 31000000

YEARS AFTER POWER UNIT START	ANNUAL OPERATION KW-HR/KW	TONS/YEAR FERTILIZER	TOTAL NH(3) SCRUBBING-FERTILIZER MFG. COST INCLUDING REGULATED ROI FOR POWER COMPANY, $/YEAR	NET FERTILIZER SALES REVENUE, $/YEAR	NET ANNUAL INCREASE (DECREASE) COST OF POWER, $	CUMULATIVE NET INCREASE (DECREASE) COST OF POWER, $	ALTERNATIVE OPERATING COST FOR WET-LIMESTONE PROCESS INCLUDING REGULATED ROI FOR POWER COMPANY, $/YEAR	ANNUAL SAVINGS (LOSS) USING NH(3) SCRUBBING-FERTILIZER INSTEAD OF WET-LIMESTONE SCRUBBING, $	CUMULATIVE SAVINGS (LOSS) USING NH(3) SCRUBBING-FERTILIZER INSTEAD OF WET-LIMESTONE SCRUBBING, $
1	7000	444000	20344500	18994300	1350200	1350200	3362400	2012200	2012200
2	7000	444000	20160200	18994300	1165900	2516100	3317000	2151100	4163300
3	7000	444000	19975900	18994300	981600	3497700	3271900	2290300	6453600
4	7000	444000	19791600	18994300	797300	4295000	3226500	2429200	8882800
5	7000	444000	19607300	18994300	613000	4908000	3181200	2568200	11451000
6	7000	444000	19423100	18994300	428800	5336800	3135800	2707000	14158000
7	7000	444000	19238800	18994300	244500	5581300	3090700	2846200	17004200
8	7000	444000	19054500	18994300	60200	5641500	3045400	2985200	19989400
9	7000	444000	18870200	18994300	(124100)	5517400	3000000	3124100	23113500
10	7000	444000	18685900	18994300	(308400)	5209000	2954900	3263300	26376800
11	5000	318000	15231900	13829800	1402100	6611100	2565100	1163000	27539800
12	5000	318000	15047600	13829800	1217800	7828900	2519800	1302000	28841800
13	5000	318000	14863300	13829800	1033500	8862400	2474500	1441000	30282800
14	5000	318000	14679100	13829800	849300	9711700	2429300	1580000	31862800
15	5000	318000	14494800	13829800	665000	10376700	2384000	1719000	33581800
16	3500	222000	11785500	9792400	1993100	12369800	2053500	60400	33642200
17	3500	222000	11601200	9792400	1808800	14178600	2008400	199600	33841800
18	3500	222000	11416900	9792400	1624500	15803100	1963100	338600	34180400
19	3500	222000	11232600	9792400	1440200	17243300	1917700	477500	34657900
20	3500	222000	11048300	9792400	1255900	18499200	1872400	616500	35274400
21	1500	95200	7334400	4304900	3029500	21528700	1496500	(1533000)	33741400
22	1500	95200	7150200	4304900	2845300	24374000	1451200	(1394100)	32347300
23	1500	95200	6965900	4304900	2661000	27035000	1405800	(1255200)	31092100
24	1500	95200	6781600	4304900	2476700	29511700	1360700	(1116000)	29976100
25	1500	95200	6597300	4304900	2292400	31804100	1315400	(977000)	28999100
26	1500	95200	6413000	4304900	2108100	33912200	1270000	(838100)	28161000
27	1500	95200	6228700	4304900	1923800	35836000	1224700	(699100)	27461900
28	1500	95200	6044400	4304900	1739500	37575500	1179500	(560000)	26901900
29	1500	95200	5856000	4304900	1551100	39126600	1134200	(416900)	26485000
30	1500	95200	5675800	4304900	1370900	40497500	1088800	(282100)	26202900
31	1500	95200	5491600	4304900	1186700	41684200	1043700	(143000)	26059900
32	1500	95200	5307300	4304900	1002400	42686600	998400	(4000)	26055900
33	1500	95200	5123000	4304900	818100	43504700	953000	134900	26190800
34	1500	95200	4938700	4304900	633800	44138500	907700	273900	26464700
35	1500	95200	4754400	4304900	449500	44588000	862500	413000	26877700
TOTAL	135000	8568000	417215500	372627500	44588000		71465700	26877700	
PRESENT WORTH IF DISCOUNTED AT 10% TO INITIAL YEAR					9470500		26463500		

Table B-161

PROCESS B. REGULATED POWER CO. ECONOMICS, 1000 MW., EXISTING UNIT, 3.5% S IN COAL, 26-19-0 FERTILIZER PRODUCTION

FIXED INVESTMENT: $ 32904000

YEARS AFTER POWER UNIT START	ANNUAL OPERA- TION KW-HR/ KW	TONS/YEAR FERTILIZER	TOTAL NH(3) SCRUBBING- FERTILIZER MFG. COST INCLUDING REGULATED ROI FOR POW- ER COMPANY, $/YEAR	NET FERTILIZER SALES REVENUE, $/YEAR	NET ANNUAL INCREASE (DECREASE) COST OF POWER, $	CUMULATIVE NET INCREASE (DECREASE) COST OF POWER, $	ALTERNATIVE OPERATING COST FOR WET -LIMESTONE PROCESS IN- CLUDING REG- ULATED ROI FOR POWER COMPANY, $/YEAR	ANNUAL SAV- INGS (LOSS) USING NH(3) SCRUBBING- FERTILIZER INSTEAD OF WET-LIME- STONE SCRUBBING, $	CUMULATIVE SAVINGS (LOSS) USING NH(3) SCRUB- BING-FERTILI- ZER INSTEAD OF WET-LIME- STONE SCRUBBING, $
1									
2									
3									
4	7000	460000	21830400	19642000	2188400	2188400	3587300	1398900	1398900
5	7000	460000	21616600	19642000	1974600	4163000	3533800	1559200	2958100
6	7000	460000	21402800	19642000	1760800	5923800	3480600	1719800	4677900
7	7000	460000	21189000	19642000	1547000	7470800	3427200	1880200	6558100
8	7000	460000	20975100	19642000	1333100	8803900	3373900	2040800	8598900
9	7000	460000	20761300	19642000	1119300	9923200	3319900	2200600	10799500
10	7000	460000	20547500	19642000	905500	10828700	3267200	2361700	13161200
11	5000	328600	16827800	14264500	2563300	13392000	2857000	293700	13454900
12	5000	328600	16613900	14264500	2349400	15741400	2803800	454400	13909300
13	5000	328600	16400100	14264500	2135600	17877000	2750300	614700	14524000
14	5000	328600	16186300	14264500	1921800	19798800	2696900	775100	15299100
15	5000	328600	15972500	14264500	1708000	21506800	2643600	935600	16234700
16	3500	230000	13050600	10129200	2921400	24428200	2294300	(627100)	15607600
17	3500	230000	12836800	10129200	2707600	27135800	2241100	(466500)	15141100
18	3500	230000	12623000	10129200	2493800	29629600	2137600	(306200)	14834900
19	3500	230000	12409200	10129200	2280000	31909600	2134400	(145600)	14689300
20	3500	230000	12195300	10129200	2066100	33975700	2080900	14800	14704100
21	1500	98500	8196400	4448300	3748100	37723800	1685300	(2062800)	12641300
22	1500	98500	7982600	4448300	3534300	41258100	1632000	(1902300)	10739000
23	1500	98500	7768800	4448300	3320500	44578600	1578600	(1741900)	8997100
24	1500	98500	7555000	4448300	3106700	47685300	1525300	(1581400)	7415700
25	1500	98500	7341100	4448300	2892800	50578100	1471900	(1420900)	5994800
26	1500	98500	7127300	4448300	2679000	53257100	1418600	(1260400)	4734400
27	1500	98500	6913500	4448300	2465200	55722300	1365200	(1100000)	3634400
28	1500	98500	6699700	4448300	2251400	57973700	1311900	(939500)	2694900
29	1500	98500	6485800	4448300	2037500	60011200	1258500	(779000)	1915900
30	1500	98500	6272000	4448300	1823700	61834900	1205000	(618700)	1297200
31	1500	98500	6058200	4448300	1609900	63444800	1151800	(458100)	839100
32	1500	98500	5844400	4448300	1396100	64840900	1098300	(297800)	541300
33	1500	98500	5630500	4448300	1182200	66023100	1045100	(137100)	404200
34	1500	98500	5416700	4448300	968400	66991500	991600	23200	427400
35	1500	98500	5202900	4448300	754600	67746100	938400	183800	611200
TOTAL	114000	7490500	393933100	326187000	67746100		68357300	611200	

PRESENT WORTH IF DISCOUNTED AT 10% TO INITIAL YEAR 19161400 26919700

Table B-162

PROCESS C. REGULATED POWER CO. ECONOMICS, 200 MW., EXISTING UNIT, 3.5% S IN COAL, 19-14-0 FERTILIZER PRODUCTION

FIXED INVESTMENT: $ 9589500

YEARS AFTER POWER UNIT START	ANNUAL OPERA-TION KW-HR/KW	TONS/YEAR FERTILIZER	TOTAL NH(3) SCRUBBING-FERTILIZER MFG. COST INCLUDING REGULATED ROI FOR POWER COMPANY, $/YEAR	NET FERTILIZER SALES REVENUE, $/YEAR	NET ANNUAL INCREASE (DECREASE) COST OF POWER, $	CUMULATIVE NET INCREASE (DECREASE) COST OF POWER, $	ALTERNATIVE OPERATING COST FOR WET-LIMESTONE PROCESS INCLUDING REGULATED ROI FOR POWER COMPANY, $/YEAR	ANNUAL SAVINGS (LOSS) USING NH(3) SCRUBBING-FERTILIZER INSTEAD OF WET-LIMESTONE SCRUBBING, $	CUMULATIVE SAVINGS (LOSS) USING NH(3) SCRUBBING-FERTILIZER INSTEAD OF WET-LIMESTONE SCRUBBING, $
1									
2									
3									
4									
5									
6									
7									
8									
9	7000	56700	5219900	1987300	3232600	3232600	1087900	(2144700)	(2144700)
10	7000	55700	5146000	1987300	3158700	6391300	1067700	(2091000)	(4235700)
11	5000	40500	4410700	1428400	2982300	9373600	947100	(2035200)	(6270900)
12	5000	40500	4336900	1428400	2908500	12282100	927000	(1981500)	(8252400)
13	5000	40500	4263000	1428400	2834600	15116700	906800	(1927800)	(10180200)
14	5000	40500	4189200	1428400	2760800	17877500	886600	(1874200)	(12054400)
15	5000	40500	4115400	1428400	2687000	20564500	866400	(1820600)	(13875000)
16	3500	28400	3519300	1007300	2512000	23076500	762900	(1749100)	(15624100)
17	3500	28400	3445500	1007300	2438200	25514700	742800	(1695400)	(17319500)
18	3500	28400	3377600	1007300	2370300	27885000	722600	(1647700)	(18967200)
19	3500	28400	3297800	1007300	2290500	30175500	702400	(1588100)	(20555300)
20	3500	28400	3224000	1007300	2216700	32392200	682200	(1534500)	(22089800)
21	1500	12200	2385800	437000	1948800	34341000	553000	(1395800)	(23485600)
22	1500	12200	2312000	437000	1875000	36216000	532800	(1342200)	(24827800)
23	1500	12200	2238200	437000	1801200	38017200	512600	(1288600)	(26116400)
24	1500	12200	2164300	437000	1727300	39744500	492400	(1234900)	(27351300)
25	1500	12200	2090500	437000	1653500	41398000	472300	(1181200)	(28532500)
26	1500	12200	2016600	437000	1579600	42977600	452100	(1127500)	(29660000)
27	1500	12200	1942800	437000	1505800	44483400	431900	(1073900)	(30733900)
28	1500	12200	1875800	437000	1438800	45922200	411700	(1027100)	(31761000)
29	1500	12200	1795100	437000	1358100	47280300	391600	(966500)	(32727500)
30	1500	12200	1721300	437000	1284300	48564600	371400	(912900)	(33640400)
31	1500	12200	1647400	437000	1210400	49775000	351200	(859200)	(34499600)
32	1500	12200	1573600	437000	1136600	50911600	331000	(805600)	(35305200)
33	1500	12200	1499700	437000	1062700	51974300	310900	(751800)	(36057000)
34	1500	12200	1425900	437000	988900	52963200	290700	(698200)	(36755200)
35	1500	12200	1352000	437000	915000	53878200	270500	(644500)	(37399700)
TOTAL	79000	640900	76586300	22708100	53878200		16478500	(37399700)	

PRESENT WORTH IF DISCOUNTED AT 10% TO INITIAL YEAR 22882000 7219600

Table B-163

PROCESS C. REGULATED POWER CO. ECONOMICS, 500 MW., NEW UNIT, 2.0% S IN COAL, 19-14-0 FERTILIZER PRODUCTION

FIXED INVESTMENT: $ 13057300

YEARS AFTER POWER UNIT START	ANNUAL OPERATION KW-HR/KW	TONS/YEAR FERTILIZER	TOTAL NH(3) SCRUBBING-FERTILIZER MFG. COST INCLUDING REGULATED ROI FOR POWER COMPANY, $/YEAR	NET FERTILIZER SALES REVENUE, $/YEAR	NET ANNUAL INCREASE (DECREASE) COST OF POWER, $	CUMULATIVE NET INCREASE (DECREASE) COST OF POWER, $	ALTERNATIVE OPERATING COST FOR WET-LIMESTONE PROCESS INCLUDING REGULATED ROI FOR POWER COMPANY, $/YEAR	ANNUAL SAVINGS (LOSS) USING NH(3) SCRUBBING-FERTILIZER INSTEAD OF WET-LIMESTONE SCRUBBING, $	CUMULATIVE SAVINGS (LOSS) USING NH(3) SCRUBBING-FERTILIZER INSTEAD OF WET-LIMESTONE SCRUBBING, $
1	7000	76600	6833700	2667200	4166500	4166500	1800000	(2366500)	(2366500)
2	7000	76600	6756100	2667200	4088900	8255400	1772900	(2316100)	(4682600)
3	7000	76600	6678600	2667200	4011400	12266800	1749100	(2262300)	(6944900)
4	7000	76600	6601000	2667200	3933800	16200600	1718800	(2215000)	(9159900)
5	7000	76600	6523400	2667200	3856200	20056800	1690600	(2165600)	(11325500)
6	7000	76600	6445800	2667200	3778600	23835400	1663400	(2115200)	(13440700)
7	7000	76600	6368300	2667200	3701100	27536500	1635900	(2065200)	(15505900)
8	7000	76600	6290700	2667200	3623500	31160000	1608700	(2014800)	(17520700)
9	7000	76600	6213100	2667200	3545900	34705900	1581200	(1964700)	(19485400)
10	7000	76600	6135500	2667200	3468300	38174200	1553800	(1914500)	(21399900)
11	5000	54700	5120900	1917800	3203100	41377300	1379800	(1823300)	(23223200)
12	5000	54700	5043300	1917800	3125500	44502800	1352300	(1773200)	(24996400)
13	5000	54700	4965700	1917800	3047900	47550700	1325100	(1722800)	(26719200)
14	5000	54700	4888100	1917800	2970300	50521000	1297900	(1672400)	(28391600)
15	5000	54700	4810600	1917800	2892800	53413800	1270400	(1622400)	(30014000)
16	3500	38300	4073200	1352000	2721200	56135000	1114100	(1607100)	(31621100)
17	3500	38300	3995600	1352000	2643600	58778600	1086700	(1556900)	(33178000)
18	3500	38300	3918000	1352000	2566000	61344600	1059200	(1506800)	(34684800)
19	3500	38300	3840400	1352000	2488400	63833000	1032000	(1456400)	(36141200)
20	3500	38300	3762800	1352000	2410800	66243800	1004500	(1406300)	(37547500)
21	1500	16400	2724300	585500	2138800	68382600	827100	(1311700)	(38859200)
22	1500	16400	2646700	585500	2061200	70443800	799800	(1261400)	(40120600)
23	1500	16400	2569100	585500	1983600	72427400	772400	(1211200)	(41331800)
24	1500	16400	2491500	585500	1906000	74333400	745100	(1160900)	(42492700)
25	1500	16400	2413900	585500	1828400	76161800	717700	(1110700)	(43603400)
26	1500	16400	2336300	585500	1750800	77912600	690400	(1060400)	(44663800)
27	1500	16400	2258800	585500	1673300	79585900	663000	(1010300)	(45674100)
28	1500	16400	2181200	585500	1595700	81181600	635500	(960200)	(46634300)
29	1500	16400	2103600	585500	1518100	82699700	608300	(909800)	(47544100)
30	1500	16400	2026000	585500	1440500	84140200	580800	(859700)	(48403800)
31	1500	16400	1948400	585500	1362900	85503100	553600	(809300)	(49213100)
32	1500	16400	1870800	585500	1285300	86788400	526100	(759200)	(49972300)
33	1500	16400	1793200	585500	1207700	87996100	498900	(708800)	(50681100)
34	1500	16400	1715600	585500	1130100	89126200	471400	(658700)	(51339800)
35	1500	16400	1638100	585500	1052600	90178800	444200	(608400)	(51948200)
TOTAL	135000	1477000	141982300	51803500	90178800		38230600	(51948200)	
PRESENT WORTH IF DISCOUNTED AT 10% TO INITIAL YEAR					32596700		14120000		

Table B-164

PROCESS C. REGULATED POWER CO. ECONOMICS, 500 MW., NEW UNIT, 3.5% S IN COAL, 19-14-0 FERTILIZER PRODUCTION

FIXED INVESTMENT: $ 16356800

YEARS AFTER POWER UNIT START	ANNUAL OPERATION KW-HR/ KW	TONS/YEAR FERTILIZER	TOTAL NH(3) SCRUBBING-FERTILIZER MFG. COST INCLUDING REGULATED ROI FOR POWER COMPANY, $/YEAR	NET FERTILIZER SALES REVENUE, $/YEAR	NET ANNUAL INCREASE (DECREASE) COST OF POWER, $	CUMULATIVE NET INCREASE (DECREASE) COST OF POWER, $	ALTERNATIVE OPERATING COST FOR WET -LIMESTONE PROCESS INCLUDING REGULATED ROI FOR POWER COMPANY, $/YEAR	ANNUAL SAVINGS (LOSS) USING NH(3) SCRUBBING-FERTILIZER INSTEAD OF WET-LIMESTONE SCRUBBING, $	CUMULATIVE SAVINGS (LOSS) USING NH(3) SCRUBBING-FERTILIZER INSTEAD OF WET-LIMESTONE SCRUBBING, $
1	7000	134000	9267000	4596200	4690800	4690800	2150200	(2540600)	(2540600)
2	7000	134000	9189900	4596200	4593700	9284500	2119600	(2474100)	(5014700)
3	7000	134000	9092700	4596200	4496500	13781000	2089200	(2407300)	(7422000)
4	7000	134000	8995600	4596200	4399400	18180400	2058700	(2340700)	(9762700)
5	7000	134000	8898500	4596200	4302300	22482700	2028100	(2274200)	(12036900)
6	7000	134000	8801400	4596200	4205200	26687900	1997500	(2207700)	(14244600)
7	7000	134000	8704200	4596200	4108000	30795900	1967100	(2140900)	(16385500)
8	7000	134000	8607000	4596200	4010800	34806700	1936600	(2074200)	(18459700)
9	7000	134000	8510000	4596200	3913800	38720500	1906000	(2007800)	(20467500)
10	7000	134000	8412800	4596200	3816600	42537100	1875600	(1941000)	(22408500)
11	5000	95700	7026000	3314100	3711900	46249000	1640100	(2071800)	(24480300)
12	5000	95700	6928800	3314100	3614700	49863700	1610000	(2004700)	(26485000)
13	5000	95700	6831700	3314100	3517600	53381300	1579400	(1938200)	(28423200)
14	5000	95700	6734500	3314100	3420400	56801700	1549000	(1871400)	(30294600)
15	5000	95700	6637400	3314100	3323300	60125000	1518400	(1804900)	(32099500)
16	3500	67000	5532700	2340300	3192400	63317400	1311600	(1880800)	(33980300)
17	3500	67000	5435500	2340300	3095200	66412600	1281200	(1814000)	(35794300)
18	3500	67000	5338400	2340300	2998100	69410700	1250600	(1747500)	(37541800)
19	3500	67000	5241300	2340300	2901000	72311700	1220100	(1680900)	(39222700)
20	3500	67000	5144100	2340300	2803800	75115500	1189700	(1614100)	(40836800)
21	1500	28700	3599000	1017700	2581300	77696800	952200	(1629100)	(42465900)
22	1500	28700	3501900	1017700	2484200	80181000	921600	(1562600)	(44028500)
23	1500	28700	3404700	1017700	2387000	82568000	891100	(1495900)	(45524400)
24	1500	28700	3307600	1017700	2289900	84857900	860700	(1429200)	(46953600)
25	1500	28700	3210500	1017700	2192800	87050700	830100	(1362700)	(48316300)
26	1500	28700	3113300	1017700	2095600	89146300	799500	(1296100)	(49612400)
27	1500	28700	3016200	1017700	1998500	91144800	769200	(1229300)	(50841700)
28	1500	28700	2919000	1017700	1901300	93046100	738400	(1162900)	(52004600)
29	1500	28700	2821900	1017700	1804200	94850300	708100	(1096100)	(53100700)
30	1500	28700	2724800	1017700	1707100	96557400	677400	(1029700)	(54130400)
31	1500	28700	2627600	1017700	1609900	98167300	647100	(962300)	(55093200)
32	1500	28700	2530400	1017700	1512700	99680000	616500	(896200)	(55989400)
33	1500	28700	2433700	1017700	1416000	101096000	585900	(830100)	(56819500)
34	1500	28700	2336200	1017700	1318500	102414500	555600	(762900)	(57582400)
35	1500	28700	2239100	1017700	1221400	103635900	525000	(696400)	(58278800)
TOTAL	135000	2564000	193135400	89499500	103635900		45357100	(58278300)	
PRESENT WORTH IF DISCOUNTED AT 10% TO INITIAL YEAR					36843600		15864900		

Table B-165

PROCESS C. REGULATED POWER CO. ECONOMICS, 500 MW., EXISTING UNIT, 3.5% S IN COAL, 19-14-0 FERTILIZER PRODUCTION

FIXED INVESTMENT: $ 17329600

YEARS AFTER POWER UNIT START	ANNUAL OPERATION KW-HR/KW	TONS/YEAR FERTILIZER	TOTAL NH(3) SCRUBBING-FERTILIZER MFG. COST INCLUDING REGULATED ROI FOR POWER COMPANY, $/YEAR	NET FERTILIZER SALES REVENUE, $/YEAR	NET ANNUAL INCREASE (DECREASE) COST OF POWER, $	CUMULATIVE NET INCREASE (DECREASE) COST OF POWER, $	ALTERNATIVE OPERATING COST FOR WET-LIMESTONE PROCESS INCLUDING REGULATED ROI FOR POWER COMPANY, $/YEAR	ANNUAL SAVINGS (LOSS) USING NH(3) SCRUBBING-FERTILIZER INSTEAD OF WET-LIMESTONE SCRUBBING, $	CUMULATIVE SAVINGS (LOSS) USING NH(3) SCRUBBING-FERTILIZER INSTEAD OF WET-LIMESTONE SCRUBBING, $
1									
2									
3									
4	7000	137000	9955800	4695000	5260800	5260800	2261500	(2999300)	(2999300)
5	7000	137000	9843300	4695000	5148300	10409100	2226100	(2922200)	(5921500)
6	7000	137000	9730700	4695000	5035700	15444800	2191000	(2844700)	(8766200)
7	7000	137000	9618200	4695000	4923200	20368000	2155600	(2767600)	(11533800)
8	7000	137000	9505700	4695000	4810700	25178700	2120500	(2690200)	(14224000)
9	7000	137000	9393200	4695000	4698200	29876900	2085100	(2613100)	(16837100)
10	7000	137000	9280600	4695000	4585600	34462500	2050000	(2535600)	(19372700)
11	5000	97900	7784300	3388300	4396000	38858500	1804000	(2592000)	(21964700)
12	5000	97900	7671800	3388300	4283500	43142000	1768900	(2514600)	(24479300)
13	5000	97900	7559200	3388300	4170900	47312900	1733500	(2437400)	(26916700)
14	5000	97900	7446700	3388300	4058400	51371300	1698300	(2360100)	(29276800)
15	5000	97900	7334200	3388300	3945900	55317200	1663000	(2282900)	(31559700)
16	3500	68500	6140200	2391300	3748900	59066100	1447600	(2301300)	(33861000)
17	3500	68500	6027600	2391300	3636300	62702400	1412300	(2224000)	(36085000)
18	3500	68500	5915100	2391300	3523800	66226200	1377100	(2146700)	(38231700)
19	3500	68500	5802600	2391300	3411300	69637500	1341800	(2069500)	(40301200)
20	3500	68500	5690000	2391300	3298700	72936200	1306600	(1992100)	(42293300)
21	1500	29400	4025400	1042200	2983200	75919400	1061200	(1922000)	(44215300)
22	1500	29400	3912900	1042200	2870700	78790100	1025900	(1844800)	(46060100)
23	1500	29400	3800400	1042200	2758200	81548300	990700	(1767500)	(47827600)
24	1500	29400	3687800	1042200	2645600	84193900	955400	(1690200)	(49517800)
25	1500	29400	3575300	1042200	2533100	86727000	920200	(1612900)	(51130700)
26	1500	29400	3462800	1042200	2420600	89147600	884900	(1535700)	(52666400)
27	1500	29400	3350200	1042200	2308000	91455600	849700	(1458300)	(54124700)
28	1500	29400	3237700	1042200	2195500	93651100	814300	(1381200)	(55505900)
29	1500	29400	3125200	1042200	2083000	95734100	779200	(1303800)	(56809700)
30	1500	29400	3012700	1042200	1970500	97704600	743800	(1226700)	(58036400)
31	1500	29400	2900100	1042200	1857900	99562500	708700	(1149200)	(59185600)
32	1500	29400	2787600	1042200	1745400	101307900	673300	(1072100)	(60257700)
33	1500	29400	2675100	1042200	1632900	102940800	638200	(994700)	(61252400)
34	1500	29400	2562600	1042200	1520400	104461200	602800	(917600)	(62170000)
35	1500	29400	2450000	1042200	1407800	105869000	567700	(840100)	(63010100)
TOTAL	114000	2232000	183265000	77396000	105869000		42858900	(63010100)	
PRESENT WORTH IF DISCOUNTED AT 10% TO INITIAL YEAR					40208100		16933200		

Table B-166

PROCESS C. REGULATED POWER CO. ECONOMICS, 500 MW., NEW UNIT, 5.0% S IN COAL, 19-14-0 FERTILIZER PRODUCTION

FIXED INVESTMENT: $ 19321300

YEARS AFTER POWER UNIT START	ANNUAL OPERATION KW-HR/KW	TONS/YEAR FERTILIZER	TOTAL NH(3) SCRUBBING-FERTILIZER MFG. COST INCLUDING REGULATED ROI FOR POWER COMPANY, $/YEAR	NET FERTILIZER SALES REVENUE, $/YEAR	NET ANNUAL INCREASE (DECREASE) COST OF POWER, $	CUMULATIVE NET INCREASE (DECREASE) COST OF POWER, $	ALTERNATIVE OPERATING COST FOR WET-LIMESTONE PROCESS INCLUDING REGULATED ROI FOR POWER COMPANY, $/YEAR	ANNUAL SAVINGS (LOSS) USING NH(3) SCRUBBING-FERTILIZER INSTEAD OF WET-LIMESTONE SCRUBBING, $	CUMULATIVE SAVINGS (LOSS) USING NH(3) SCRUBBING-FERTILIZER INSTEAD OF WET-LIMESTONE SCRUBBING, $
1	7000	191400	11569200	6482700	5086500	5086500	2506500	(2580000)	(2580000)
2	7000	191400	11454500	6482700	4971800	10058300	2473000	(2498800)	(5078800)
3	7000	191400	11339600	6482700	4856900	14915200	2439300	(2417600)	(7496400)
4	7000	191400	11224800	6482700	4742100	19657300	2405900	(2336300)	(9832700)
5	7000	191400	11110000	6482700	4627300	24284600	2372100	(2255200)	(12087900)
6	7000	191400	10995200	6482700	4512500	28797100	2338600	(2173900)	(14261800)
7	7000	191400	10880400	6482700	4397700	33194800	2304900	(2092800)	(16354600)
8	7000	191400	10765500	6482700	4282800	37477600	2271500	(2011300)	(18365900)
9	7000	191400	10650700	6482700	4168000	41645600	2238000	(1930000)	(20295900)
10	7000	191400	10535900	6482700	4053200	45698800	2204300	(1848900)	(22144800)
11	5000	136700	8723100	4684700	4038400	49737200	1903900	(2134500)	(24279300)
12	5000	136700	8608300	4684700	3923600	53660800	1870200	(2053400)	(26332700)
13	5000	136700	8493500	4684700	3808800	57469600	1836700	(1972100)	(28304800)
14	5000	136700	8378600	4684700	3693900	61163500	1803000	(1890900)	(30195700)
15	5000	136700	8263800	4684700	3579100	64742600	1769500	(1809600)	(32005300)
16	3500	95700	6828200	3314100	3514100	68256700	1512100	(2002000)	(34007300)
17	3500	95700	6713400	3314100	3399300	71656000	1478400	(1920900)	(35928200)
18	3500	95700	6598600	3314100	3284500	74940500	1444900	(1839600)	(37767800)
19	3500	95700	6483800	3314100	3169700	78110200	1411300	(1758400)	(39526200)
20	3500	95700	6369000	3314100	3054800	81165000	1377800	(1677000)	(41203200)
21	1500	41000	4371900	1446100	2925800	84090800	1078200	(1847600)	(43050800)
22	1500	41000	4257100	1446100	2811000	86901800	1044700	(1766300)	(44817100)
23	1500	41000	4142300	1446100	2696200	89598000	1011900	(1684300)	(46501400)
24	1500	41000	4027500	1446100	2581400	92179400	977500	(1603900)	(48105300)
25	1500	41000	3912700	1446100	2466600	94646000	944000	(1522600)	(49627900)
26	1500	41000	3797900	1446100	2351800	96997800	910300	(1441500)	(51069400)
27	1500	41000	3683000	1446100	2236900	99234700	876800	(1360100)	(52429500)
28	1500	41000	3568200	1446100	2122100	101356800	843100	(1279000)	(53708500)
29	1500	41000	3453400	1446100	2007300	103364100	809600	(1197700)	(54906200)
30	1500	41000	3338600	1446100	1892500	105256600	776200	(1116300)	(56022500)
31	1500	41000	3223800	1446100	1777700	107034300	742500	(1035200)	(57057700)
32	1500	41000	3109000	1446100	1662900	108697200	708900	(954100)	(58011800)
33	1500	41000	2994200	1446100	1548100	110245300	675300	(872800)	(58884600)
34	1500	41000	2879300	1446100	1433200	111678500	641800	(791400)	(59676000)
35	1500	41000	2764500	1446100	1318400	112996900	608100	(710300)	(60386300)
TOTAL	135000	3691000	239509400	126512500	112996900		52610600	(60386300)	

PRESENT WORTH IF DISCOUNTED AT 10% TO INITIAL YEAR 39847900 19662100

Table B-167

PROCESS C, REGULATED POWER CO. ECONOMICS, 1000 MW., NEW UNIT, 3.5% S IN COAL, 19-14-0 FERTILIZER PRODUCTION

FIXED INVESTMENT: $ 24639300

YEARS AFTER POWER UNIT START	ANNUAL OPERATION KW-HR/KW	TONS/YEAR FERTILIZER	TOTAL NH(3) SCRUBBING-FERTILIZER MFG. COST INCLUDING REGULATED ROI FOR POWER COMPANY, $/YEAR	NET FERTILIZER SALES REVENUE, $/YEAR	NET ANNUAL INCREASE (DECREASE) COST OF POWER, $	CUMULATIVE NET INCREASE (DECREASE) COST OF POWER, $	ALTERNATIVE OPERATING COST FOR WET-LIMESTONE PROCESS INCLUDING REGULATED ROI FOR POWER COMPANY, $/YEAR	ANNUAL SAVINGS (LOSS) USING NH(3) SCRUBBING-FERTILIZER INSTEAD OF WET-LIMESTONE SCRUBBING, $	CUMULATIVE SAVINGS (LOSS) USING NH(3) SCRUBBING-FERTILIZER INSTEAD OF WET-LIMESTONE SCRUBBING, $
1	7000	259500	15145900	8677700	6468200	6468200	3362400	(3105800)	(3105800)
2	7000	259500	14999600	8677700	6321900	12790100	3317000	(3004900)	(6110700)
3	7000	259500	14853400	8677700	6175700	18965800	3271900	(2903800)	(9014500)
4	7000	259500	14707200	8677700	6029500	24995300	3226500	(2803000)	(11817500)
5	7000	259500	14561000	8677700	5883300	30878600	3181200	(2702100)	(14519600)
6	7000	259500	14414800	8677700	5737100	36615700	3135900	(2601300)	(17120900)
7	7000	259500	14268500	8677700	5590800	42206500	3090700	(2500100)	(19621000)
8	7000	259500	14122300	8677700	5444600	47651100	3045400	(2399200)	(22020200)
9	7000	259500	13976100	8677700	5298400	52949500	3000000	(2298400)	(24318600)
10	7000	259500	13830000	8677700	5152300	58101800	2954900	(2197400)	(26516000)
11	5000	185400	11404500	6286900	5117600	63219400	2565100	(2552500)	(29068500)
12	5000	185400	11258300	6286900	4971400	68190800	2519900	(2451600)	(31520100)
13	5000	185400	11112100	6286900	4825200	73016000	2474500	(2350700)	(33870800)
14	5000	185400	10965900	6286900	4679000	77695000	2429300	(2249700)	(36120500)
15	5000	185400	10819600	6286900	4532700	82227700	2384000	(2148700)	(38269200)
16	3500	129800	8903300	4456000	4447300	86675000	2053500	(2393800)	(40663000)
17	3500	129800	8757100	4456000	4301100	90976100	2008400	(2292700)	(42955700)
18	3500	129800	8610900	4456000	4154900	95131000	1963100	(2191800)	(45147500)
19	3500	129800	8464700	4456000	4008700	99139700	1917700	(2091000)	(47238500)
20	3500	129800	8318400	4456000	3862400	103002100	1872400	(1990000)	(49228500)
21	1500	55600	5658800	1949300	3709500	106711600	1496500	(2213000)	(51441500)
22	1500	55600	5512600	1949300	3563300	110274900	1451200	(2112100)	(53553600)
23	1500	55600	5366400	1949300	3417100	113692000	1405800	(2011300)	(55564900)
24	1500	55600	5220100	1949300	3270800	116962800	1360700	(1910100)	(57475000)
25	1500	55600	5073900	1949300	3124600	120087400	1315400	(1809200)	(59284200)
26	1500	55600	4927700	1949300	2978400	123065800	1270000	(1708400)	(60992600)
27	1500	55600	4781400	1949300	2832100	125897900	1224700	(1607400)	(62600000)
28	1500	55600	4635200	1949300	2685900	128583800	1179500	(1506400)	(64106400)
29	1500	55600	4489000	1949300	2539700	131123500	1134200	(1405500)	(65511900)
30	1500	55600	4342800	1949300	2393500	133517000	1088900	(1304700)	(66816600)
31	1500	55600	4196600	1949300	2247300	135764300	1043700	(1203600)	(68020200)
32	1500	55600	4050400	1949300	2101100	137865400	998400	(1102700)	(69122900)
33	1500	55600	3904100	1949300	1954800	139820200	953000	(1001800)	(70124700)
34	1500	55600	3757900	1949300	1808600	141628800	907700	(900900)	(71025600)
35	1500	55600	3611700	1949300	1662400	143291200	862500	(799900)	(71825500)
TOTAL	135000	5005000	313022200	169731000	143291200		71465700	(71825500)	
PRESENT WORTH IF DISCOUNTED AT 10% TO INITIAL YEAR					50606500		26463500		

Table B-168

PROCESS C. REGULATED POWER CO. ECONOMICS, 1000 MW., EXISTING UNIT, 3.5% S IN COAL, 19-14-0 FERTILIZER PRODUCTION

FIXED INVESTMENT: $ 26646400

YEARS AFTER POWER UNIT START	ANNUAL OPERATION KW-HR/KW	TONS/YEAR FERTILIZER	TOTAL NH(3) SCRUBBING-FERTILIZER MFG. COST INCLUDING REGULATED ROI FOR POWER COMPANY, $/YEAR	NET FERTILIZER SALES REVENUE, $/YEAR	NET ANNUAL INCREASE (DECREASE) COST OF POWER, $	CUMULATIVE NET INCREASE (DECREASE) COST OF POWER, $	ALTERNATIVE OPERATING COST FOR WET-LIMESTONE PROCESS INCLUDING REGULATED ROI FOR POWER COMPANY, $/YEAR	ANNUAL SAVINGS (LOSS) USING NH(3) SCRUBBING-FERTILIZER INSTEAD OF WET-LIMESTONE SCRUBBING, $	CUMULATIVE SAVINGS (LOSS) USING NH(3) SCRUBBING-FERTILIZER INSTEAD OF WET-LIMESTONE SCRUBBING, $
1									
2									
3									
4	7000	268000	16142700	8951200	7191500	7191500	3587300	(3604200)	(3604200)
5	7000	268000	15969700	8951200	7018500	14210000	3533800	(3484700)	(7088900)
6	7000	268000	15796600	8951200	6845400	21055400	3480600	(3364800)	(10453700)
7	7000	268000	15623600	8951200	6672400	27727800	3427200	(3245200)	(13698900)
8	7000	268000	15450500	8951200	6499300	34227100	3373900	(3125400)	(16824300)
9	7000	268000	15277500	8951200	6326300	40553400	3319900	(3006400)	(19830700)
10	7000	268000	15104400	8951200	6153200	46706600	3267200	(2886000)	(22716700)
11	5000	191400	12550700	6482700	6068000	52774600	2857000	(3211000)	(25927700)
12	5000	191400	12377600	6482700	5894900	58669500	2803800	(3091100)	(29018800)
13	5000	191400	12204500	6482700	5721800	64391300	2750300	(2971500)	(31990300)
14	5000	191400	12031500	6482700	5548800	69940100	2696900	(2851900)	(34842200)
15	5000	191400	11858400	6482700	5375700	75315800	2643600	(2732100)	(37574300)
16	3500	134000	9834900	4596200	5238700	80554500	2294300	(2944400)	(40518700)
17	3500	134000	9661800	4596200	5065600	85620100	2241100	(2824500)	(43343200)
18	3500	134000	9488700	4596200	4892500	90512600	2187600	(2704900)	(46048100)
19	3500	134000	9315700	4596200	4719500	95232100	2134400	(2585100)	(48633200)
20	3500	134000	9142600	4596200	4546400	99778500	2080900	(2465500)	(51098700)
21	1500	57400	6340400	2011300	4329100	104107600	1685300	(2643800)	(53742500)
22	1500	57400	6167300	2011300	4156000	108263600	1632000	(2524000)	(56266500)
23	1500	57400	5994300	2011300	3983000	112246600	1578600	(2404400)	(58670900)
24	1500	57400	5821200	2011300	3809900	116056500	1525300	(2284600)	(60955500)
25	1500	57400	5648200	2011300	3636900	119693400	1471900	(2165000)	(63120500)
26	1500	57400	5475100	2011300	3463800	123157200	1418600	(2045200)	(65165700)
27	1500	57400	5302000	2011300	3290700	126447900	1365200	(1925500)	(67091200)
28	1500	57400	5129000	2011300	3117700	129565600	1311900	(1805800)	(68897000)
29	1500	57400	4956000	2011300	2944700	132510300	1258500	(1686200)	(70583200)
30	1500	57400	4782900	2011300	2771600	135281900	1205000	(1566600)	(72149800)
31	1500	57400	4609800	2011300	2598500	137880400	1151800	(1446700)	(73596500)
32	1500	57400	4436800	2011300	2425500	140305900	1098300	(1327200)	(74923700)
33	1500	57400	4263700	2011300	2252400	142558300	1045100	(1207300)	(76131000)
34	1500	57400	4090700	2011300	2079400	144637700	991600	(1087800)	(77218800)
35	1500	57400	3917600	2011300	1906300	146544000	938400	(967900)	(78186700)
TOTAL	114000	4364000	294766400	148222400	146544000		68357300	(78186700)	
PRESENT WORTH IF DISCOUNTED AT 10% TO INITIAL YEAR					55036300		26919700		

APPENDIX C
DRAWINGS

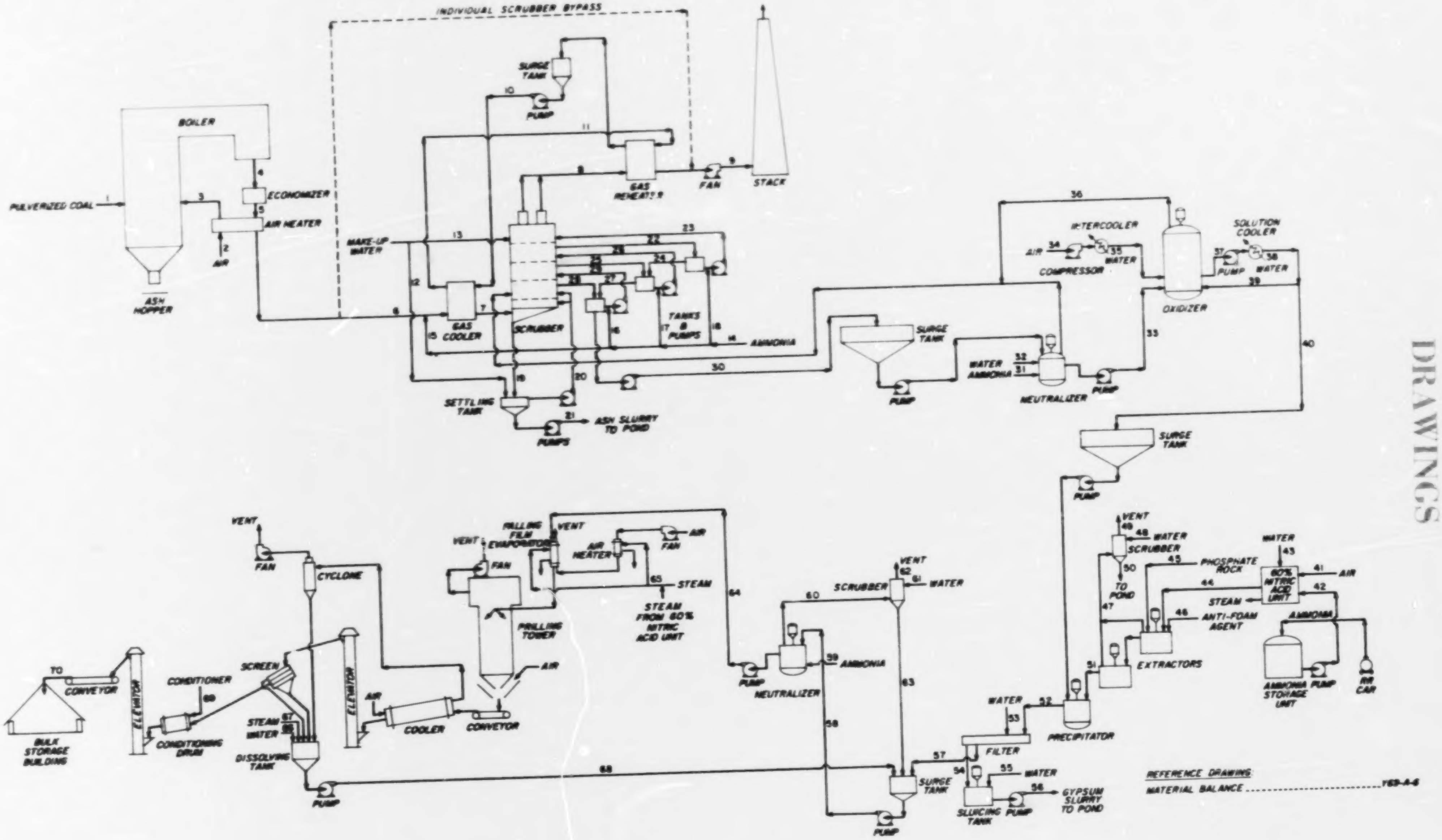

INDIVIDUAL SCRUBBER BYPASS
BOILER
PULVERIZED COAL
1
2
AIR
3
4
ECONOMIZER
5
AIR HEATER
ASH HOPPER
6
MAKE-UP WATER
12
13
GAS COOLER
7
15
SCRUBBER
8
GAS REHEATER
SURGE TANK
10
PUMP
11
FAN
9
STACK
23
22
26
25
28
24
29
27
16
17
18
TANKS & PUMPS
14
AMMONIA
19
20
SETTLING TANK
PUMPS
21
ASH SLURRY TO POND
30
SURGE TANK
PUMP
WATER
32
AMMONIA
31
NEUTRALIZER
PUMP
33
36
AIR
34
COMPRESSOR
INTERCOOLER
35
WATER
OXIDIZER
SOLUTION COOLER
37
PUMP
38
WATER
39
40
SURGE TANK
PUMP
VENT
49
48
WATER
SCRUBBER
50
TO POND
45
PHOSPHATE ROCK
44
STEAM
46
ANTI-FOAM AGENT
47
EXTRACTORS
51
WATER
43
60% NITRIC ACID UNIT
41
AIR
42
AMMONIA
AMMONIA STORAGE UNIT
PUMP
RR CAR
52
PRECIPITATOR
WATER
53
FILTER
57
54
55
WATER
SLUICING TANK
PUMP
56
GYPSUM SLURRY TO POND
SURGE TANK
PUMP
VENT
62
61
WATER
SCRUBBER
60
63
NEUTRALIZER
59
AMMONIA
PUMP
58
64
FALLING FILM EVAPORATOR
VENT
AIR HEATER
FAN
AIR
65
STEAM
STEAM FROM 60% NITRIC ACID UNIT
VENT
FAN
PRILLING TOWER
AIR
CONVEYOR
COOLER
AIR
ELEVATOR
VENT
FAN
CYCLONE
SCREEN
STEAM
67
WATER
66
DISSOLVING TANK
PUMP
68
CONDITIONER
69
CONDITIONING DRUM
ELEVATOR
TO
CONVEYOR
BULK STORAGE BUILDING
REFERENCE DRAWING:
MATERIAL BALANCE Y63-A-6

Figure C-1. Flowsheet—Process A

STREAM NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
DESCRIPTION	COAL TO BOILER	COMBUSTION AIR TO AIR HEATER	COMBUSTION AIR TO BOILER	GAS TO ECONOMIZER	GAS TO AIR HEATER	GAS TO COOLER	GAS TO SCRUBBER	GAS TO REHEATER	GAS TO STACK	WARM WATER TO GAS COOLER	HOT WATER TO GAS REHEATER	WATER TO SETTLING TANK	MAKE-UP WATER TO SCRUBBER	AMMONIA TO SCRUBBER	AMMONIA TO GAS COOLER	AMMONIA TO 2ND RECYCLE PUMP	AMMONIA TO 3RD RECYCLE PUMP	AMMONIA TO 4TH RECYCLE PUMP	ASH SLURRY TO SETTLING TANK	RECYCLE TO 1ST PLATE
RATE, LBS./HR	375M	4,777M	4,309M	4,657M	4,657M	1,281M	1,281M	1,312M	1,312M	339M	339M	79.2M	16M	2,224	29	1,684	342	169	374M	384M
SCFM	-	1,046M	943M	997M	997M	274M	274M	285M	285M	-	-	-	-	827	11	626	127	63	-	-
GPM	-	-	-	-	-	-	-	-	-	689	729	158	32	-	-	-	-	-	741	768
PARTICULATES, LBS./HR.	-	-	-	33.7M	33.7M	8,435	8,435	35	35											
TEMPERATURE, °F	AMBIENT	110	610	890	705	310	172	115	280	143	280	65	65							
SPECIFIC GRAVITY																			101	
VISCOSITY, CPS																				
UNDISSOLVED SOLIDS, %																			28	
pH																				

STREAM NO.	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
DESCRIPTION	ASH SLURRY TO POND	DRAIN TO 4TH PLATE TANK	RECYCLE TO 4TH PLATE	OVERFLOW TO 3RD PLATE TANK	DRAIN TO 3RD PLATE TANK	RECYCLE TO 3RD PLATE	OVERFLOW TO 2ND PLATE TANK	DRAIN TO 2ND PLATE TANK	RECYCLE TO 2ND PLATE	SOLUTION TO SURGE TANK	AMMONIA TO NEUTRALIZER	WATER TO NEUTRALIZER	SOLUTION TO OXIDIZER	AIR TO COMPRESSOR	WATER TO INTERCOOLER	GAS TO SCRUBBER	SOLUTION TO PUMP	WATER TO SOLUTION COOLER	RECYCLE SOLUTION TO OXIDIZER	SOLUTION TO PRECIPITATOR
RATE, LBS./HR.	69.6M	170M	154M	16.2M	161M	161M	16.5M	192M	192M	72.8M	2,927	22.8M	49.2M	28.8M	156M	28.7M	613M	1,058M	582M	102M
SCFM	-	-	-	-	-	-	-	-	-	-	1,089	-	-	6,260	-	6,067	-	-	-	-
GPM	130	341	309	32.4	309	309	31.8	309	309	116	-	45.5	82.8	-	312	-	1,005	2,116	922	186
PARTICULATES, LBS./HR.																				
TEMPERATURE, °F										120		68	188	95	65		185	65	135	135
SPECIFIC GRAVITY	1.07			1.00			1.04			1.24			1.19				1.22		1.23	1.23
VISCOSITY, CPS				0.8			0.7			5.6			1.6				1.8		2.2	2.2
UNDISSOLVED SOLIDS, %	12									0.3			0.2							0.2
pH																				

STREAM NO.	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
DESCRIPTION	AIR TO 60% NITRIC ACID UNIT	AMMONIA TO 60% NITRIC ACID UNIT	WATER TO 60% NITRIC ACID UNIT	NITRIC ACID TO EXTRACTOR	ROCK TO EXTRACTOR	ANTI-FOAM AGENT TO EXTRACTOR	GAS TO SCRUBBER	WATER TO SCRUBBER	GAS TO VENT	LIQUOR TO POND	PRODUCT TO PRECIPITATOR	SLURRY TO FILTER	WATER TO FILTER	CAKE TO SLUICING TANK	WATER TO SLUICING TANK	SLURRY TO POND	FILTRATE TO SURGE TANK	SOLUTION TO NEUTRALIZER	AMMONIA TO NEUTRALIZER	GAS TO SCRUBBER
RATE, LBS./HR	284M	13.3M	8,491M	77.9M	41.3M	16.8	1,855	373	1,519	709	117M	219M	50.9M	74.7M	241M	315M	195M	241M	5,653	4,883
SCFM	61.9M	4,840	-	-	-	-	310	-	244	-	-	-	-	-	-	-	-	-	2,103	1,719
GPM	-	-	11M	118	-		-	0.75	-	1.13	149	345	101	-	482	556	329	403	-	-
PARTICULATES, LBS./HR																				
TEMPERATURE, °F	90		65				165	65	120	120	165	190	65		65			100		190
SPECIFIC GRAVITY				1.38																
VISCOSITY, CPS																				
UNDISSOLVED SOLIDS, %																20				
pH																				

STREAM NO.	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
DESCRIPTION	WATER TO SCRUBBER	GAS TO VENT	LIQUOR TO SURGE TANK	SOLUTION TO EVAPORATOR	STEAM TO EVAPORATION SYSTEM	WATER TO DISSOLVING TANK	STEAM TO DISSOLVING TANK	SOLUTION TO SURGE TANK	CONDITIONER TO DRUM	PRODUCT TO STORAGE										
RATE, LBS./HR	1,039	4,688	1,267	242M	179M	19.5M	2,811	44.6M	1,736	66.8M										
SCFM	-	1,635	-	-	-	-	-	-	-	-										
GPM	2.08	-	2.72	403	-	39	-	71.4	-	-										
PARTICULATES, LBS./HR																				
TEMPERATURE, °F	65	120	120	150		65		100												
SPECIFIC GRAVITY			0.93	1.2				1.25												
VISCOSITY, CPS																				
UNDISSOLVED SOLIDS, %																				
pH																				

NOTES

1. CALCULATIONS BASED ON:
   - a. 3.5% SULFUR IN COAL (DRY BASIS)
   - b. 12% ASH COAL (AS FIRED BASIS)
   - c. 92% OF SULFUR IN COAL EVOLVES AS SO_2
   - d. 75% OF ASH IN COAL EVOLVES AS FLY ASH
   - e. MISCELLANEOUS INFORMATION FROM SCRUBBER MANUFACTURER
   - f. 99.6% REMOVAL OF PARTICULATES TO SCRUBBERS
   - g. 90% SO_2 REMOVAL
2. PARTICULATES SHOULD BE ADDED TO GAS TO GET TOTAL STREAM RATE
3. STREAM NUMBERS 6-29 ARE ONE OF FOUR SIMILAR STREAMS
4. STREAM NUMBERS 33-39 ARE ONE OF TWO SIMILAR STREAMS

SYMBOL IN TABLE
M.....THOUSAND

REFERENCE DRAWING
PROCESS FLOW DIAGRAM A69-A-9

Figure C-2. Material Balance—Process A

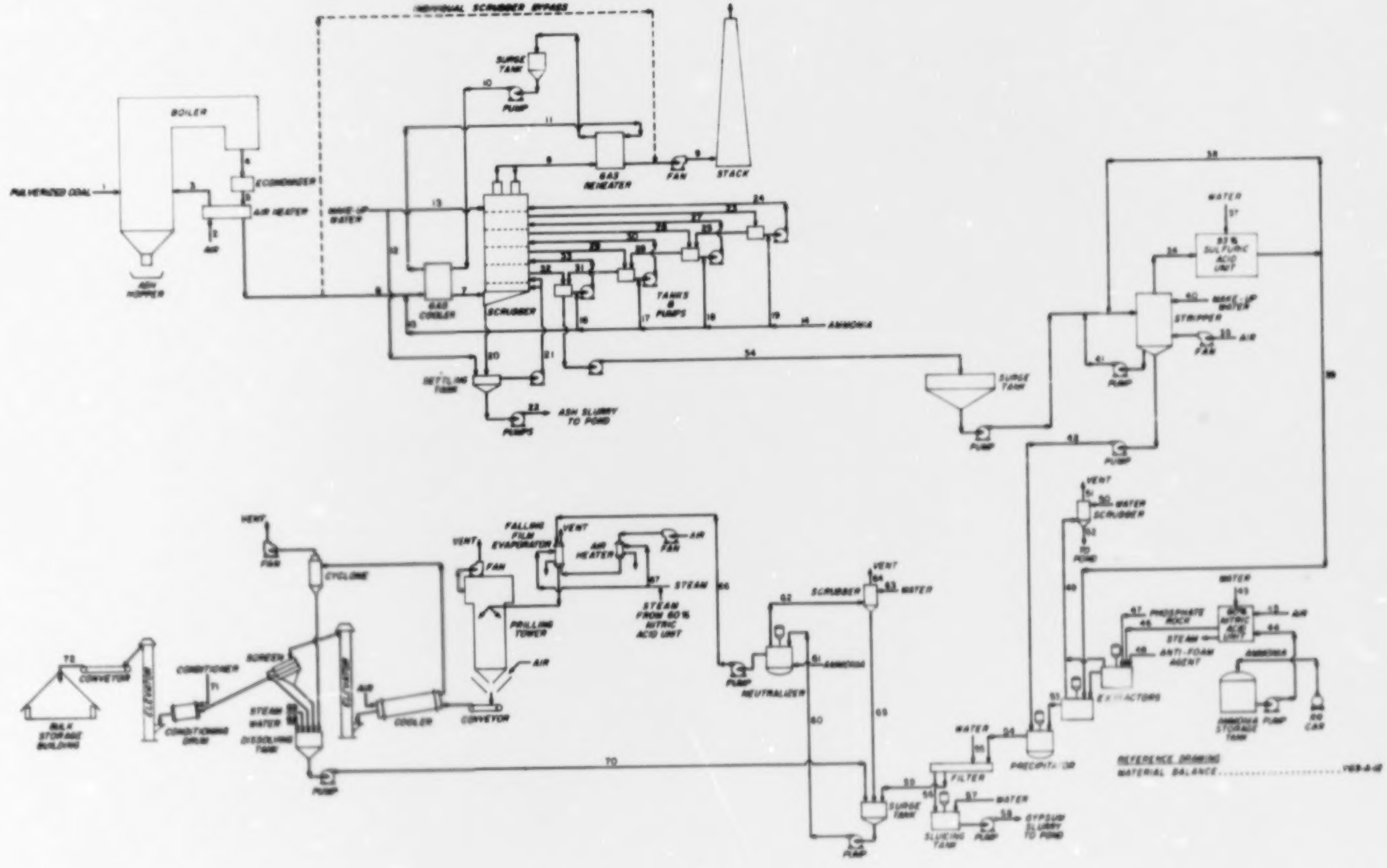

INDIVIDUAL SCRUBBER BYPASS
BOILER
PULVERIZED COAL
ECONOMIZER
AIR HEATER
AIR
ASH HOPPER
MAKE-UP WATER
SURGE TANK
PUMP
GAS REHEATER
FAN
STACK
GAS COOLER
SCRUBBER
TANKS & PUMPS
AMMONIA
SETTLING TANK
PUMPS
ASH SLURRY TO POND
SURGE TANK
PUMP
WATER
93 % SULFURIC ACID UNIT
MAKE-UP WATER
STRIPPER
FAN
AIR
PUMP
VENT
WATER
SCRUBBER
TO POND
PHOSPHATE ROCK
60% NITRIC ACID UNIT
STEAM
ANTI-FOAM AGENT
AMMONIA
EXTRACTORS
AMMONIA STORAGE TANK
PUMP
RR CAR
PRECIPITATOR
FILTER
SURGE TANK
SLUICING TANK
GYPSUM SLURRY TO POND
REFERENCE DRAWING
MATERIAL BALANCE Y69-A-12
VENT
FAN
CYCLONE
FALLING FILM EVAPORATOR
AIR HEATER
STEAM
STEAM FROM 60 % NITRIC ACID UNIT
PRILLING TOWER
SCRUBBER
NEUTRALIZER
SCREEN
CONDITIONER
CONDITIONING DRUM
ELEVATOR
COOLER
CONVEYOR
DISSOLVING TANK
BULK STORAGE BUILDING

Figure C-3. Flowsheet—Process B

STREAM NO	1	2	3	4	5	6	7	8	9	10
DESCRIPTION	COAL TO BOILER	COMBUSTION AIR TO AIR HEATER	COMBUSTION AIR TO BOILER	GAS TO ECONOMIZER	GAS TO AIR HEATER	GAS TO COOLER	GAS TO SCRUBBER	GAS TO REHEATER	GAS TO STACK	WARM WATER TO GAS COOLER
RATE, LBS./HR	375M	4,777M	4,309M	4,657M	4,657M	1,281M	1,281M	1,299M	1,299M	339M
SCFM	-	1,046M	943M	997M	997M	274M	274M	282M	282M	-
GPM	-	-	-	-	-	-	-	-	-	689
PARTICULATES, LBS./HR.	-	-	-	33.7M	33.7M	8,435	8,435	25	25	
TEMPERATURE, °F	AMBIENT	110	610	890	705	310	172	115	250	143
SPECIFIC GRAVITY										
VISCOSITY, CPS										
UNDISSOLVED SOLIDS, %										
pH										

STREAM NO	11	12	13	14	15	16	17	18	19	20
DESCRIPTION	HOT WATER TO GAS REHEATER	WATER TO SETTLING TANK	MAKE-UP WATER TO SCRUBBER	AMMONIA TO SCRUBBER	AMMONIA TO GAS COOLER	AMMONIA TO 2ND RECYCLE PUMP	AMMONIA TO 3RD RECYCLE PUMP	AMMONIA TO 4TH RECYCLE PUMP	AMMONIA TO 5TH RECYCLE PUMP	ASH SLURRY TO SETTLING TANK
RATE, LBS./HR	339M	79.2M	15M	1,942	29	723	637	341	212	374M
SCFM	-	-	-	722	11	269	237	127	78	-
GPM	729	158	30	-	-	-	-	-	-	741
PARTICULATES, LBS./HR.										
TEMPERATURE, °F	280	65	65							
SPECIFIC GRAVITY										1.01
VISCOSITY, CPS										
UNDISSOLVED SOLIDS, %										28
pH										

STREAM NO.	21	22	23	24	25	26	27	28	29	30
DESCRIPTION	RECYCLE TO 1ST PLATE	ASH SLURRY TO POND	DRAIN TO 5TH PLATE TANK	RECYCLE TO 5TH PLATE	OVERFLOW TO 4TH PLATE TANK	DRAIN TO 4TH PLATE TANK	RECYCLE TO 4TH PLATE	OVERFLOW TO 3RD PLATE TANK	DRAIN TO 3RD PLATE TANK	RECYCLE TO 3RD PLATE
RATE, LBS./HR	384M	69.6M	169M	154M	15.2M	164M	164M	15.6M	179M	179M
SCFM	-	-	-	-	-	-	-	-	-	-
GPM	768	130	339	309	30.4	308	309	28.3	309	309
PARTICULATES, LBS./HR.										
TEMPERATURE, °F										
SPECIFIC GRAVITY		1.07			1.00			1.08		
VISCOSITY, CPS					0.6			0.8		
UNDISSOLVED SOLIDS, %		12								
pH										

STREAM NO.	31	32	33	34	35	36	37	38	39	40
DESCRIPTION	OVERFLOW TO 2ND PLATE TANK	DRAIN TO 2ND PLATE TANK	RECYCLE TO 2ND PLATE	SOLUTION TO SURGE TANK	AIR TO FAN	GAS TO 93% SULFURIC ACID UNIT	WATER TO SULFURIC ACID UNIT	SULFURIC ACID TO SOLUTION	SULFURIC ACID TO EXTRACTOR	MAKE-UP WATER TO STRIPPER
RATE, LBS./HR	16.2M	195M	195M	67.8M	21.9M	44.1M	770M	21.7M	11.4M	1,280
SCFM	-	-	-	-	4,810	7,404	-	-	-	-
GPM	27.9	309	309	108	-	-	1,540	24.1	12.7	2.56
PARTICULATES, LBS./HR.										
TEMPERATURE, °F				120	95	114	65			65
SPECIFIC GRAVITY	1.16			1.26				1.80		
VISCOSITY, CPS	1.7			6.7						
UNDISSOLVED SOLIDS, %				0.3						
pH										

STREAM NO	41	42	43	44	45	46	47	48	49	50
DESCRIPTION	RECYCLE TO SOLUTION	SOLUTION TO PRECIPITATOR	AIR TO 60% NITRIC ACID UNIT	AMMONIA TO 60% NITRIC ACID UNIT	WATER TO 60% NITRIC ACID UNIT	NITRIC ACID TO EXTRACTOR	ROCK TO EXTRACTOR	ANTI-FOAM AGENT TO EXTRACTOR	GAS TO SCRUBBER	WATER TO SCRUBBER
RATE, LBS./HR	14.7M	68.7M	188M	8,776	3,630M	91.5M	10.5M	16.2	1,825	387
SCFM	-	-	41M	3,265	-	-	-	-	305	-
GPM	23.9	112	-	-	7,260	76.3	-		-	0.73
PARTICULATES, LBS./HR.										
TEMPERATURE, °F		114	95		65				165	65
SPECIFIC GRAVITY		1.23				1.35				
VISCOSITY, CPS		1.8								
UNDISSOLVED SOLIDS, %		0.3								
pH										

STREAM NO	51	52	53	54	55	56	57	58	59	60
DESCRIPTION	GAS TO VENT	LIQUOR TO POND	PRODUCT TO PRECIPITATOR	SLURRY TO FILTER	WATER TO FILTER	CAKE TO SLUICING TANK	WATER TO SLUICING TANK	SLURRY TO POND	FILTRATE TO SURGE TANK	SOLUTION TO NEUTRALIZER
RATE, LBS./HR	1,494	699	102M	170M	49.6M	73.4M	236M	310M	146M	181M
SCFM	240	-	-	-	-	-	-	-	-	-
GPM	-	1.11	129	288	99.1	-	473	548	247	308
PARTICULATES, LBS./HR.										
TEMPERATURE, °F	120	120	165	150	65		65			100
SPECIFIC GRAVITY										
VISCOSITY, CPS										
UNDISSOLVED SOLIDS, %								20		
pH										

STREAM NO	61	62	63	64	65	66	67	68	69	70
DESCRIPTION	AMMONIA TO NEUTRALIZER	GAS TO SCRUBBER	WATER TO SCRUBBER	GAS TO VENT	LIQUOR TO SURGE TANK	SOLUTION TO EVAPORATOR	STEAM TO EVAPORATION SYSTEM	WATER TO DISSOLVING TANK	STEAM TO DISSOLVING TANK	SOLUTION TO SURGE TANK
RATE, LBS./HR	5,204	6,003	948	5,795	1,186	181M	129M	14.8M	2,128	33.8M
SCFM	1,936	2,112	-	2,035	-	-	-	-	-	-
GPM	-	-	1.90	-	2.49	301	-	29.5	-	54.1
PARTICULATES, LBS./HR.										
TEMPERATURE, °F		150	65	120	120	180		65		100
SPECIFIC GRAVITY					0.98	1.2				1.25
VISCOSITY, CPS										
UNDISSOLVED SOLIDS, %										
pH										

STREAM NO	71	72	73	74	75	76	77	78	79	80
DESCRIPTION	CONDITIONER TO DRUM	PRODUCT TO STORAGE								
RATE, LBS./HR	1,314	65.7M								
SCFM	-	-								
GPM	-	-								
PARTICULATES, LBS./HR.										
TEMPERATURE, °F										
SPECIFIC GRAVITY										
VISCOSITY, CPS										
UNDISSOLVED SOLIDS, %										
pH										

NOTES

1 CALCULATIONS BASED ON
- a 3.5% SULFUR IN COAL (DRY BASIS)
- b 12% ASH COAL (AS FIRED BASIS)
- c 92% OF SULFUR IN COAL EVOLVES AS SO_2
- d 75% OF ASH IN COAL EVOLVES AS FLY ASH
- e MISCELLANEOUS INFORMATION FROM SCRUBBER MANUFACTURER
- f 99.7% REMOVAL OF PARTICULATES TO SCRUBBERS
- g 90% SO_2 REMOVAL

2 PARTICULATES SHOULD BE ADDED TO GAS TO GET TOTAL STREAM RATE

3 STREAM NUMBERS 6-33 ARE ONE OF FOUR SIMILAR STREAMS

SYMBOL IN TABLE

M.....THOUSAND

REFERENCE DRAWING:

PROCESS FLOW DIAGRAM..............................A69-A-11

Figure C-4. Material Balance—Process B

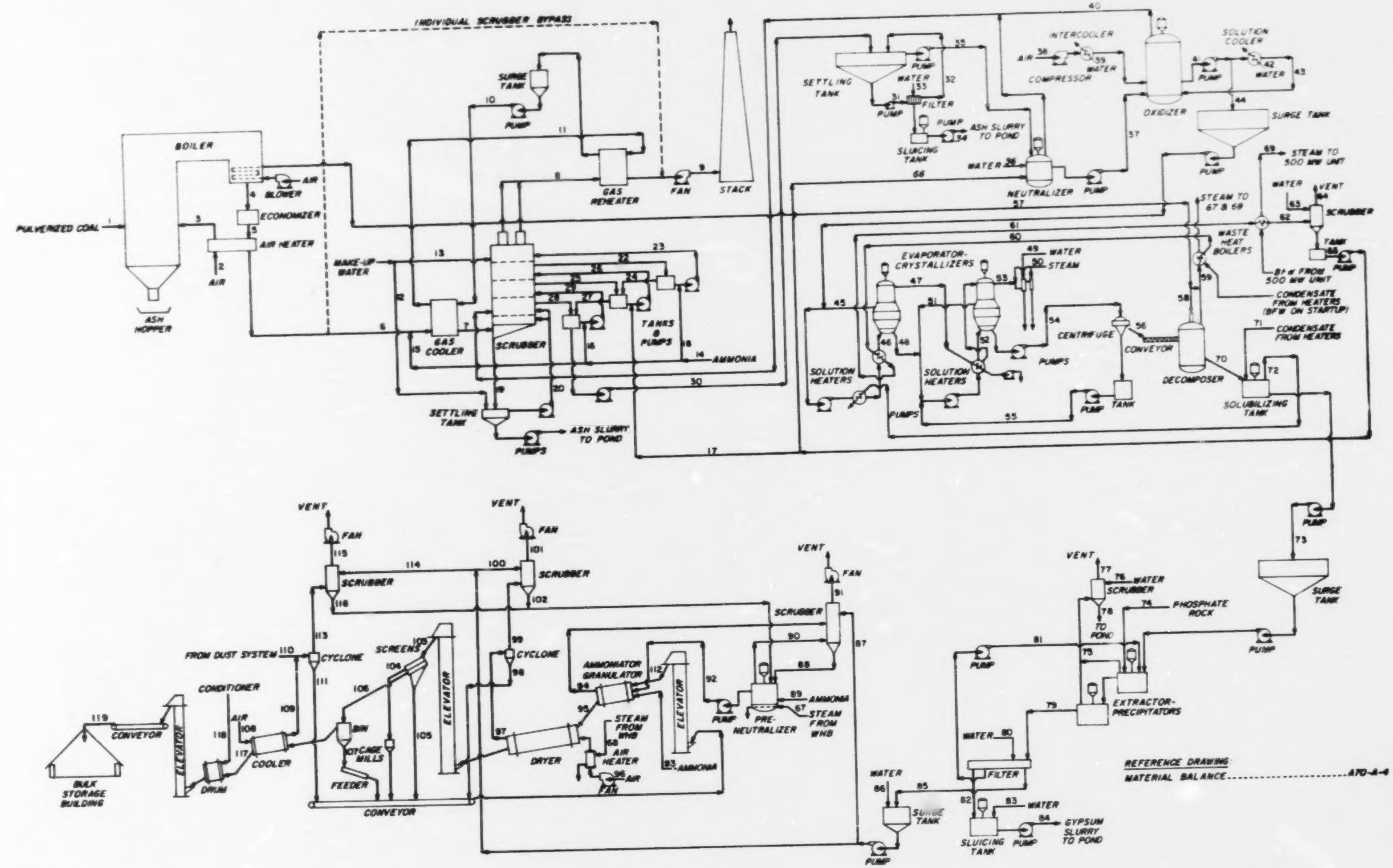

(INDIVIDUAL SCRUBBER BYPASS)
PULVERIZED COAL
BOILER
ASH HOPPER
BLOWER
AIR
ECONOMIZER
AIR HEATER
MAKE-UP WATER
SURGE TANK
PUMP
GAS REHEATER
FAN
STACK
GAS COOLER
SCRUBBER
TANKS & PUMPS
AMMONIA
SETTLING TANK
PUMPS
ASH SLURRY TO POND
SETTLING TANK
WATER
FILTER
SLUICING TANK
ASH SLURRY TO POND
NEUTRALIZER
INTERCOOLER
COMPRESSOR
OXIDIZER
SOLUTION COOLER
SURGE TANK
STEAM TO 500 MW UNIT
VENT
SCRUBBER
TANK
STEAM TO 67 & 68
WASTE HEAT BOILERS
BFW FROM 500 MW UNIT
CONDENSATE FROM HEATERS (BFW ON STARTUP)
CONDENSATE FROM HEATERS
EVAPORATOR-CRYSTALLIZERS
STEAM
SOLUTION HEATERS
CENTRIFUGE
CONVEYOR
DECOMPOSER
SOLUBILIZING TANK
SURGE TANK
PHOSPHATE ROCK
TO POND
EXTRACTOR-PRECIPITATORS
REFERENCE DRAWING:
MATERIAL BALANCE A70-4-4
GYPSUM SLURRY TO POND
SLUICING TANK
PRE-NEUTRALIZER
STEAM FROM WHB
ELEVATOR
AMMONIATOR GRANULATOR
AIR HEATER
DRYER
CYCLONE
SCREENS
CAGE MILLS
BIN
FEEDER
CONVEYOR
FROM DUST SYSTEM
CONDITIONER
COOLER
DRUM
BULK STORAGE BUILDING

Figure C-5. Flowsheet—Process C

STREAM NO	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
DESCRIPTION	COAL TO BOILER	COMBUSTION AIR TO AIR HEATER	COMBUSTION AIR TO BOILER	GAS TO ECONOMIZER	GAS TO AIR HEATER	GAS TO COOLER	GAS TO SCRUBBER	GAS TO REHEATER	GAS TO STACK	WARM WATER TO GAS COOLER	HOT WATER TO GAS REHEATER	WATER TO SETTLING TANK	MAKE-UP WATER TO SCRUBBER	AMMONIA TO SCRUBBER	AMMONIA TO GAS COOLER	AMMONIA TO 2ND RECYCLE PUMP	NH_4OH TO 3RD RECYCLE PUMP	AMMONIA TO 4TH RECYCLE PUMP	ASH SLURRY TO SETTLING TANK	RECYCLE TO 1ST PLATE	ASH SLURRY TO POND	DRAIN TO 4TH PLATE TANK	RECYCLE TO 4TH PLATE	OVERFLOW TO 3RD PLATE TANK	DRAIN TO 3RD PLATE TANK
RATE, LBS/HR	375M	4,777M	4,308M	4,657M	4,657M	1,281M	1,281M	1,312M	1,318M	330M	330	79.2M	14.4M	1,862	29	1,684	2,012	149	374M	384M	69.6M	170M	154M	16.2M	[illegible]
SCFM	-	1,046M	943M	997M	997M	274M	274M	285M	285M	-	-	-	-	883	11	626	-	35.4	-	-	-	-	-	-	-
GPM	-	-	-	-	-	-	-	-	-	669	729	138	28.8	-	-	-	433	-	741	768	130	341	309	32.4	[illegible]
PARTICULATES, LBS/HR	-	-	-	33.7M	33.7M	8,433	8,433	38	38																
TEMPERATURE, °F	AMBIENT	110	610	880	703	310	172	115	280	143	[illegible]	65	65												
SPECIFIC GRAVITY																			1.01		1.07			1.00	
VISCOSITY, CPS																								0.6	
UNDISSOLVED SOLIDS, %																			2.8		12				
pH																									

STREAM NO	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
DESCRIPTION	RECYCLE TO 3RD PLATE	OVERFLOW TO 2ND PLATE TANK	DRAIN TO 2ND PLATE TANK	RECYCLE TO 2ND PLATE	SOLUTION TO SETTLING TANK	SETTLED SOLUTION TO FILTER	FILTRATE TO SETTLING TANK	WATER TO FILTER	ASH SLURRY TO POND	SOLUTION TO NEUTRALIZER	WATER TO NEUTRALIZER	SOLUTION TO OXIDIZER	AIR TO COMPRESSOR	WATER TO INTERCOOLER	GAS TO SCRUBBER	SOLUTION TO PUMP	WATER TO SOLUTION COOLER	RECYCLE SOLUTION TO OXIDIZER	SOLUTION TO SURGE TANK	SOLUTION TO RECYCLE	SOLUTION TO 1ST EFFECT	VAPOR TO SOLUTION HEATER	SOLUTION TO 2ND EFFECT	WATER TO CONDENSING SYSTEM	STEAM TO CONDENSING SYSTEM
RATE, LBS/HR	163M	16.3M	192M	192M	72.8M	13.3M	13.1M	1,487	1,667	72.6M	9,430	49.9M	28.5M	156M	26.7M	559M	920M	508M	102M	6,250M	6,352M	27.3M	74.7M	564M	1,133
SCFM	-	-	-	-	-	-	-	-	-	-	-	-	6,280	-	6,067	-	-	-	-	-	-	9,593	-	-	399
GPM	313	31.8	309	309	117	21.3	21.2	293	312	117	18.9	81.9	-	312	-	916	1,840	834	187	10M	10.18M	-	119	1,130	-
PARTICULATES, LBS/HR																									
TEMPERATURE, °F					120			65			65	163	95	65		165	65	135	188	195	201	195	135	65	338
SPECIFIC GRAVITY		1.04			1.24	1.23	1.24		1.07	1.24		1.20				1.22		1.23							
VISCOSITY, CPS		0.7			5.6					5.6		1.6				1.6		2.2							
UNDISSOLVED SOLIDS, %					0.3	1.5	-		18	-															
pH																									

STREAM NO	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75
DESCRIPTION	SOLUTION TO RECYCLE	SOLUTION TO 2ND EFFECT	VAPOR TO CONDENSING SYSTEM	$(NH_4)_2SO_4$ SLURRY TO CENTRIFUGE	LIQUOR TO RECYCLE	$(NH_4)_2SO_4$ TO CONVEYOR	HOT AIR TO DECOMPOSER & PRI. W.H.B.	HOT AIR TO DECOMPOSER	GAS TO PRI. W.H.B.	GAS TO SEC. SLN HTR	GAS TO SEC. W.H.B.	GAS TO SCRUBBER	WATER TO SCRUBBER	GAS TO VENT	NH_4OH TO PUMP	NH_4OH TO NEUTRALIZER	STEAM TO PRE-NEUTRALIZER	STEAM TO DRYER AIR HEATER	STEAM TO 500 MW UNIT	MELT TO SOLUBILIZING TANK	COND TO SOLUBILIZING TANK	VAPOR TO PRI SLN HTR	SOLUTION TO SURGE TANK	ROCK TO EXTRACTOR-PRECIPITATOR	GAS TO SCRUBBER
RATE, LBS/HR	6,250M	6,504M	29.4M	224M	179M	40.2M	633M	270M	640M	640M	640M	640M	28.2M	642M	24.3M	16.3M	31.1M	35.9M	29.9M	18.9M	17.7M	9.9M	53.5M	17.2M	1,623
SCFM	-	-	10.4M	-	-	-	140M	59.5M	142M	142M	142M	142M	-	142M	-	-	11.0M	12.6M	10.9M	-	-	3,465	-	-	456
GPM	10M	10.4M	-	337	[illegible]	-	-	-	-	-	-	-	52.4	-	52.3	35.0	-	-	-		35.5	-	770	-	-
PARTICULATES, LBS/HR																									
TEMPERATURE, °F	131	138	131	131	130	130	1,000	1,000	748	[illegible]	334	140	65	120	120		365	365	180	700	209	220	220		165
SPECIFIC GRAVITY																									
VISCOSITY, CPS																									
UNDISSOLVED SOLIDS, %																									
pH																									

STREAM NO	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
DESCRIPTION	WATER TO SCRUBBER	GAS TO VENT	LIQUOR TO POND	SLURRY TO FILTER	WATER TO FILTER	WATER TO EXTRACTOR-PRECIPITATOR	CAKE TO SLUICING TANK	WATER TO SLUICING TANK	SLURRY TO POND	FILTRATE TO SURGE TANK	WATER TO SURGE TANK	SOLUTION TO SCRUBBER	SOLUTION TO PRE-NEUTRALIZER	AMMONIA TO PRE-NEUTRALIZER	GAS TO SCRUBBER	GAS TO FAN	SLURRY TO AMMONIATOR-GRANULATOR	AMMONIA TO AMMONIATOR-GRANULATOR	GAS TO SCRUBBER	PRODUCT TO DRYER	AIR TO FAN	GAS TO CYCLONE	DUST TO CONVEYOR	GAS TO SCRUBBER	SOLUTION TO SCRUBBER
RATE, LBS/HR	890	1,482	681	110M	40.4M	40.4M	38.0M	103M	135M	775M	12M	8,590	7,160	1,669	25.5M	37.0M	38.9M	662	10.1M	80M	[illegible]	912M	2,380	912M	65.7M
SCFM	-	411	-	-	-	-	-	-	-	-	-	-	-	617	6,985	12.1M	-	346	2,840	-	110M	114M	-	116M	-
GPM	1.1	-	130	183	80.9	80.9	-	206	238	168	24	14.2	11.4	-	-	-	182	-	-		-	-	-	-	109
PARTICULATES, LBS/HR																						4,760		2,380	
TEMPERATURE, °F	65	180	180	165	65			65		116	65		180		230	120	230		180	180	95	210	185	209	
SPECIFIC GRAVITY									1.13	1.29		1.21	1.26												1.21
VISCOSITY, CPS																									
UNDISSOLVED SOLIDS, %									20																
pH																									

STREAM NO	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125
DESCRIPTION	AIR TO FAN	SOLUTION TO PRE-NEUTRALIZER	FEED TO SCREENS	OVERSIZE TO CAGE MILLS	FINES TO CONVEYOR	PRODUCT TO BIN	PRODUCT TO FEEDER	AIR TO COOLER	AIR TO CYCLONE	AIR TO CYCLONE	DUST TO CONVEYOR	RECYCLE TO AMMONIATOR-GRANULATOR	AIR TO SCRUBBER	SOLUTION TO SCRUBBER	AIR TO FAN	SOLUTION TO PRE-NEUTRALIZER	PRODUCT TO CONDITIONING DRUM	CONDITIONER TO DRUM	PRODUCT TO STORAGE						
RATE, LBS/HR	523M	57.3M	402M	737M	99.1M	320M	381M	92.2M	92.2M	94.3M	615	486M	136M	15.2M	137M	15.3M	37.6M	787	58.3M						
SCFM	116M	-	-	-	-	-	-	11.5M	11.8M	160	-	-	293M	-	297M	-	-	-	-						
GPM	-	940	-	-	-	-	-	-	-	-	-	-	-	29.2	-	24.5	-	-	-						
PARTICULATES, LBS/HR	51								486	738			615		13										
TEMPERATURE, °F	120	120	180			165		95	188	115		180			120	120	115								
SPECIFIC GRAVITY		1.26												1.21		1.23									
VISCOSITY, CPS																									
UNDISSOLVED SOLIDS, %																									
pH																									

NOTES

1 CALCULATIONS BASED ON
- a 3.5% SULFUR IN COAL (DRY BASIS)
- b 12% ASH COAL (AS FIRED BASIS)
- c 95% OF SULFUR IN COAL EVOLVES AS SO_2
- d 75% OF ASH IN COAL EVOLVES AS FLY ASH
- e MISCELLANEOUS INFORMATION FROM SCRUBBER MANUFACTURER
- f 99.6% REMOVAL OF PARTICULATES TO SCRUBBERS
- g 90% SO_2 REMOVAL

2 PARTICULATES SHOULD BE ADDED TO GAS TO GET TOTAL STREAM RATE

3 STREAM NUMBERS 6-29 ARE ONE OF FOUR SIMILAR STREAMS

4 STREAM NUMBERS 37-43, 59 AND 70-72 ARE ONE OF TWO SIMILAR STREAMS

REFERENCE DRAWING

PROCESS FLOW DIAGRAM .... [illegible]

Figure C-6. Material Balance—Process C

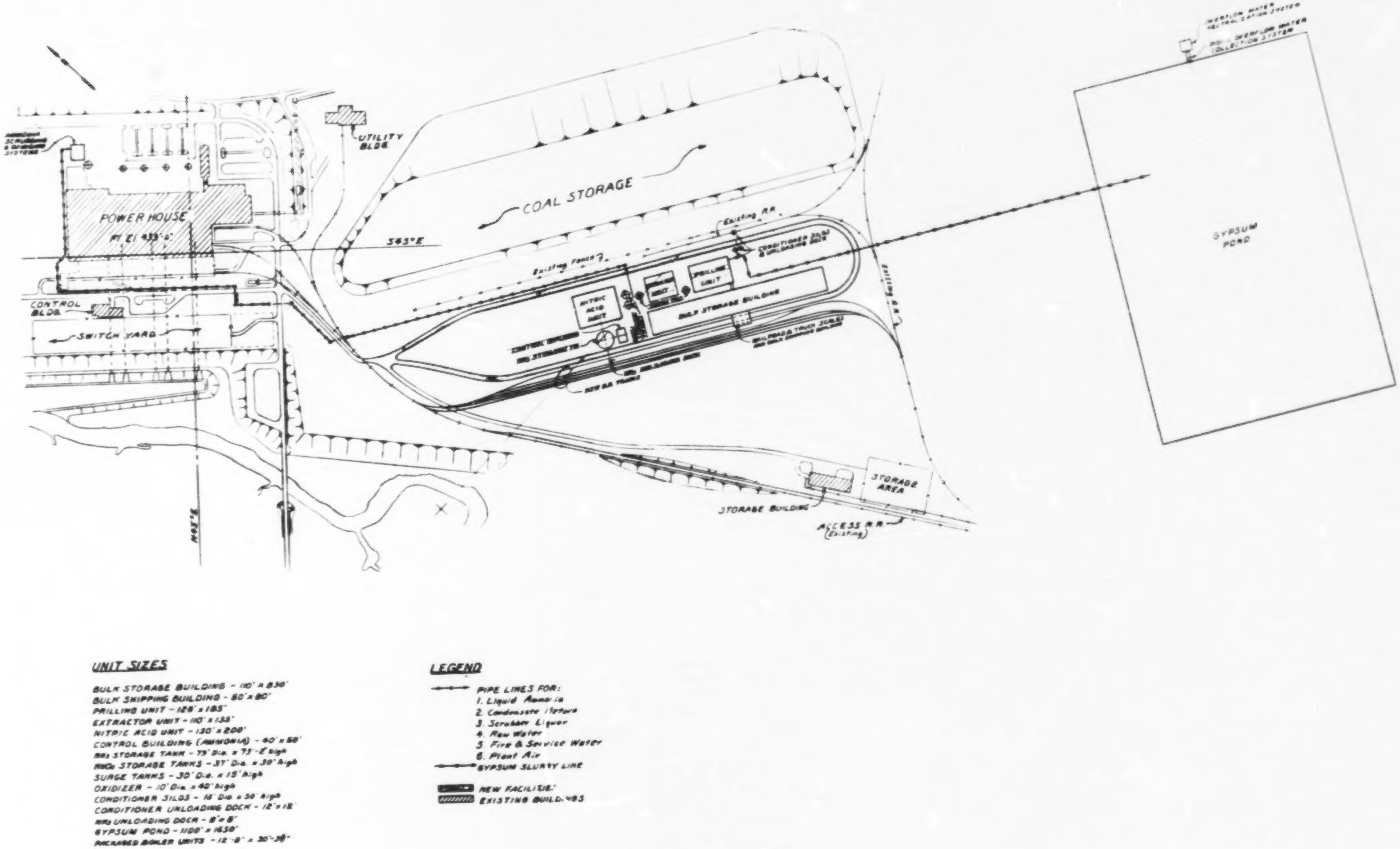

OVERFLOW WATER NEUTRALIZATION SYSTEM
POND OVERFLOW WATER COLLECTION SYSTEM
UTILITY BLDG.
COAL STORAGE
POWER HOUSE
Fl. El. 433'-0"
343°E
CONTROL BLDG.
SWITCH YARD
Existing Fence
Existing R.R.
CONDITIONER SILOS & UNLOADING DOCK
NITRIC ACID UNIT
PRILLING UNIT
UNIT
BULK STORAGE BUILDING
RAILROAD & TRUCK SCALES AND BULK SHIPPING BUILDING
NEW R.R. TRACKS
Existing R.R.
GYPSUM POND
STORAGE AREA
STORAGE BUILDING
ACCESS R.R. (Existing)
UNIT SIZES
BULK STORAGE BUILDING - 110' x 830'
BULK SHIPPING BUILDING - 60' x 80'
PRILLING UNIT - 128' x 185'
EXTRACTOR UNIT - 110' x 135'
NITRIC ACID UNIT - 130' x 200'
CONTROL BUILDING (AMMONIA) - 40' x 60'
NH_3 STORAGE TANK - 73' Dia. x 73'-6" high
HNO_3 STORAGE TANKS - 37' Dia. x 30' high
SURGE TANKS - 30' Dia. x 15' high
OXIDIZER - 10' Dia. x 40' high
CONDITIONER SILOS - 18' Dia. x 30' high
CONDITIONER UNLOADING DOCK - 12' x 12'
NH_3 UNLOADING DOCK - 8' x 8'
GYPSUM POND - 1100' x 1650'
PACKAGED BOILER UNITS - 12'-8" x 30'-38"
LEGEND
PIPE LINES FOR:
1. Liquid Ammonia
2. Condensate Return
3. Scrubber Liquor
4. Raw Water
5. Fire & Service Water
6. Plant Air
GYPSUM SLURRY LINE
NEW FACILITIES
EXISTING BUILDINGS

Figure C-7. Plot Plan

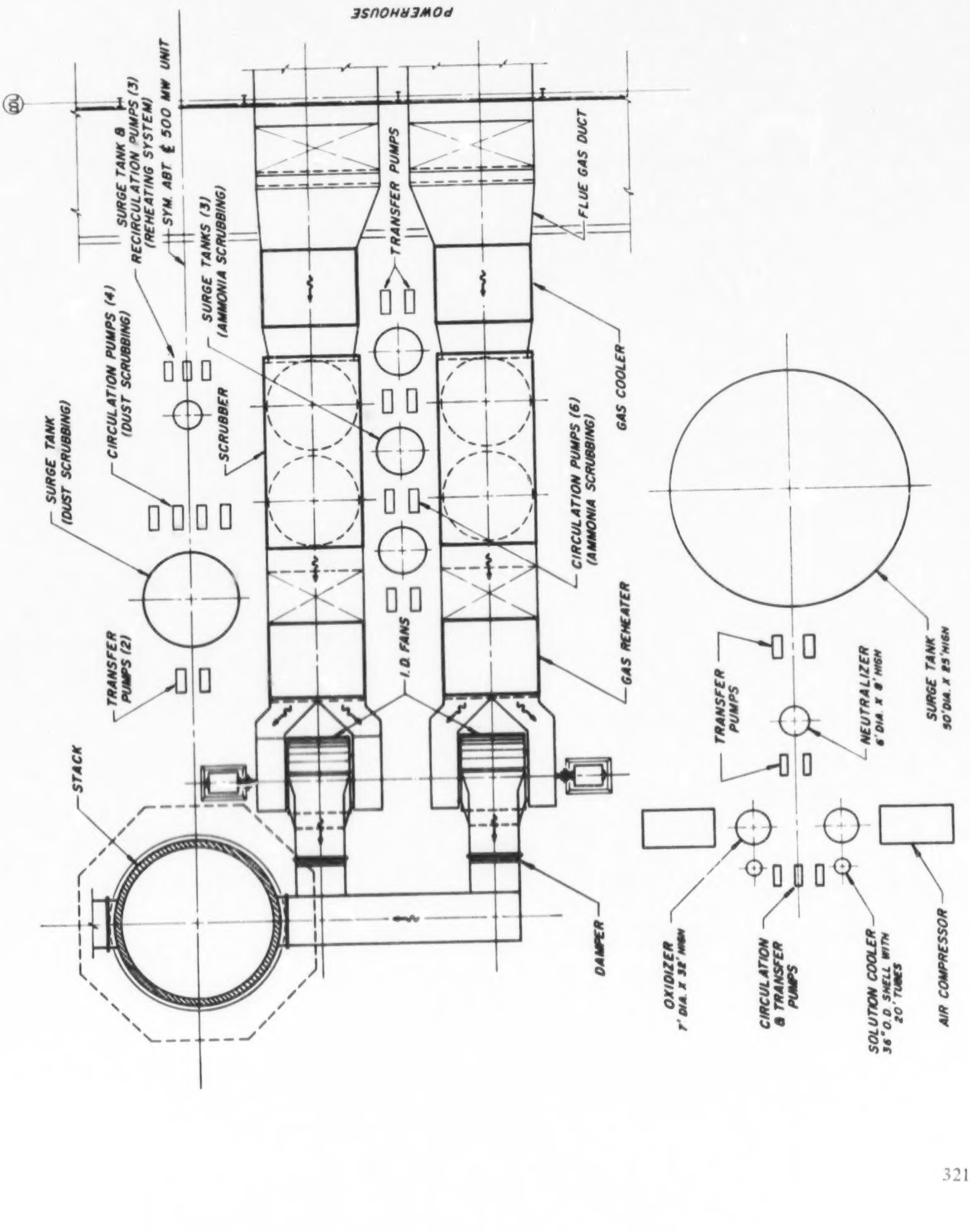

POWERHOUSE
SURGE TANK & RECIRCULATION PUMPS (3) (REHEATING SYSTEM)
SYM. ABT. ℄ 500 MW UNIT
SURGE TANKS (3) (AMMONIA SCRUBBING)
TRANSFER PUMPS
FLUE GAS DUCT
CIRCULATION PUMPS (4) (DUST SCRUBBING)
SURGE TANK (DUST SCRUBBING)
SCRUBBER
GAS COOLER
CIRCULATION PUMPS (6) (AMMONIA SCRUBBING)
GAS REHEATER
TRANSFER PUMPS (2)
I.D. FANS
STACK
DAMPER
TRANSFER PUMPS
NEUTRALIZER 6' DIA. X 8' HIGH
SURGE TANK 90' DIA. X 25' HIGH
OXIDIZER 7' DIA. X 32' HIGH
CIRCULATION & TRANSFER PUMPS
SOLUTION COOLER 36" O.D. SHELL WITH 20' TUBES
AIR COMPRESSOR

Figure C-8. Plan View

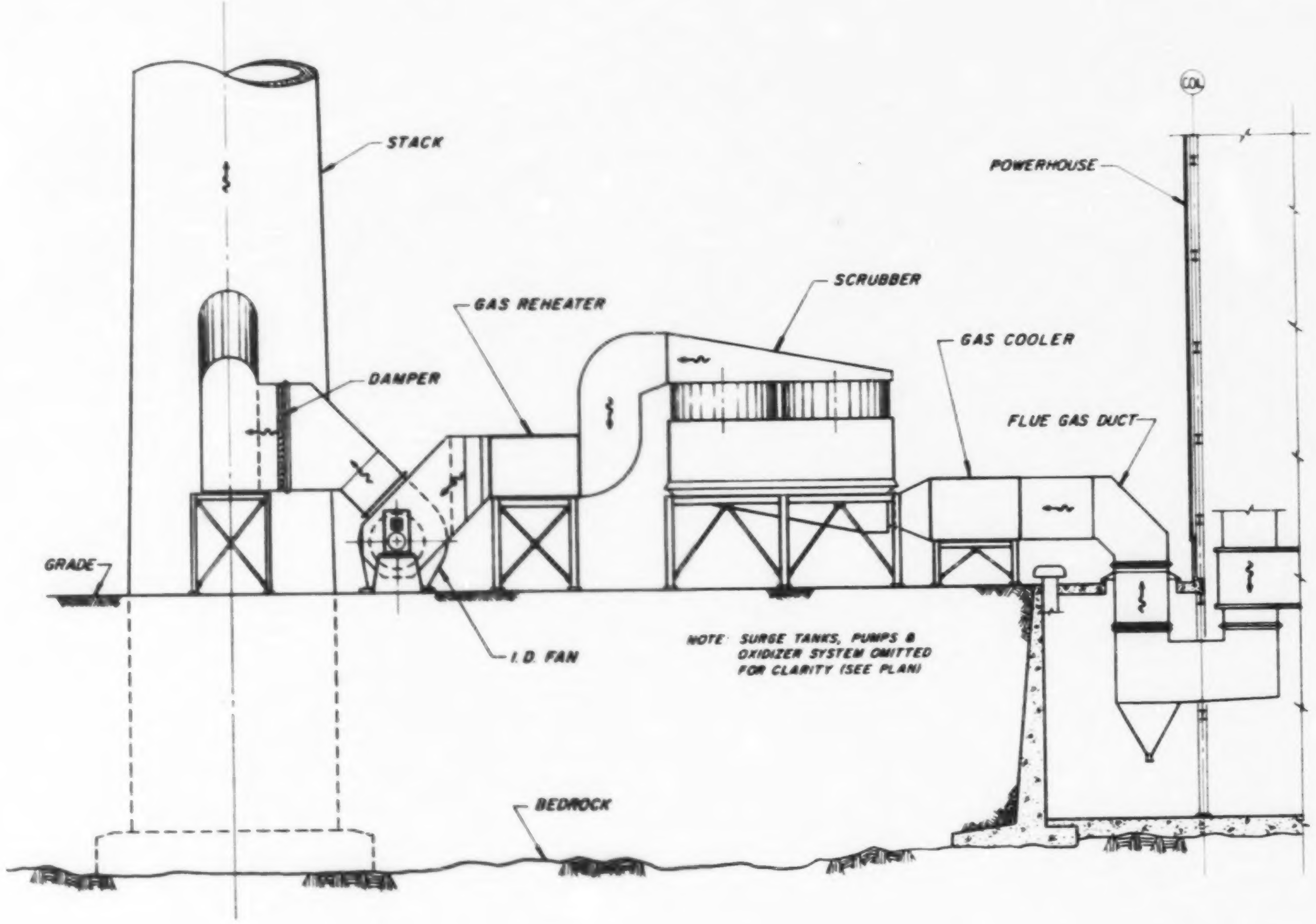

STACK
POWERHOUSE
SCRUBBER
GAS REHEATER
GAS COOLER
DAMPER
FLUE GAS DUCT
GRADE
I.D. FAN
NOTE: SURGE TANKS, PUMPS & OXIDIZER SYSTEM OMITTED FOR CLARITY (SEE PLAN)
BEDROCK
COL

Figure C-9. Elevation View